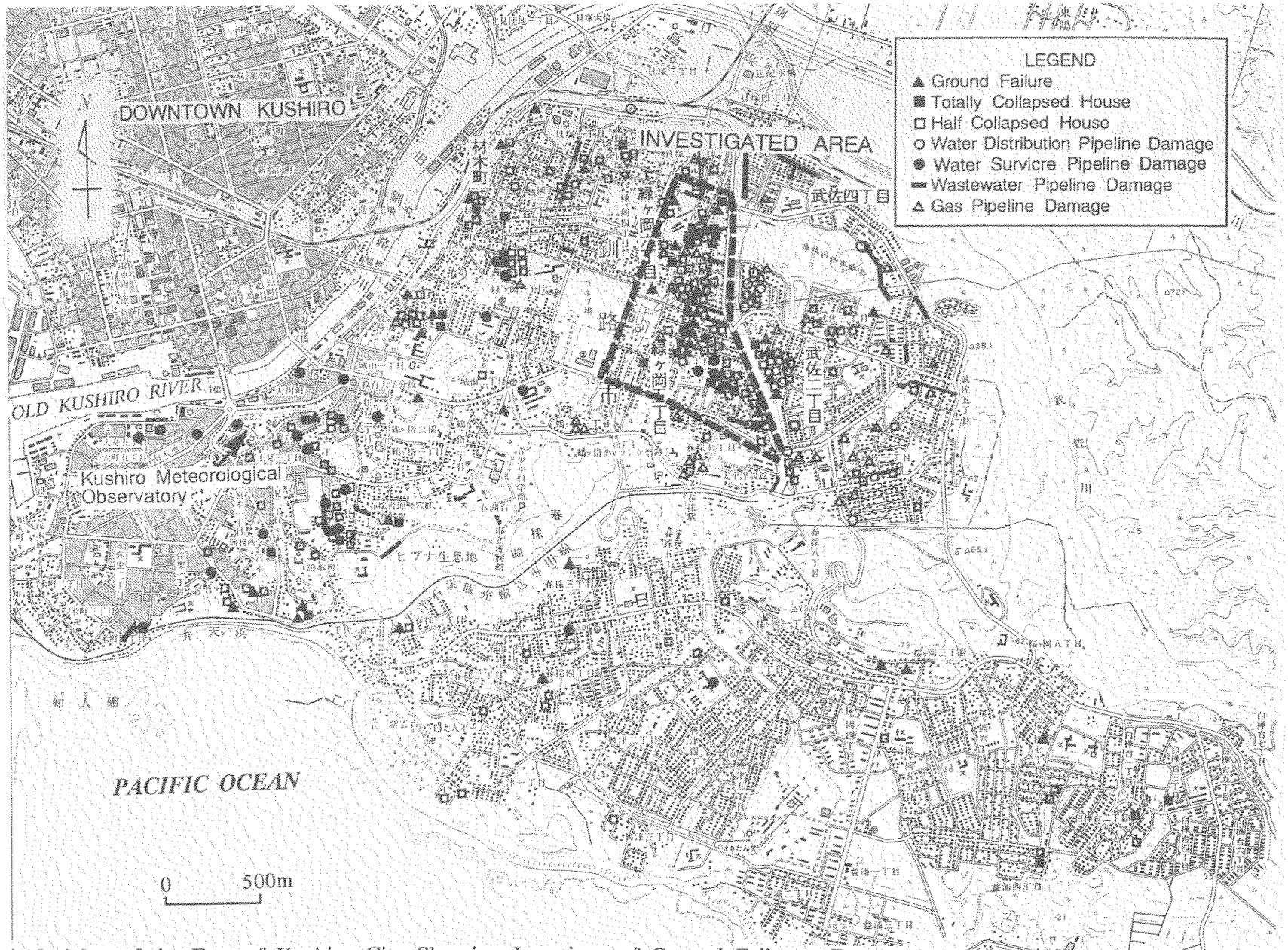

Fig.3 Map of the East of Kushiro City Showing Locations of Ground Failures, Damage to Structures and a Zone Investigated

Strong motions were recorded at the Kushiro Meteorological Observatory which is located about 2.5 km southwest of Midorigaoka and 14 km north of the epicenter (see Fig.3 for location). Figure 4 shows a time record of acceleration. The peak acceleration and velocity are 711 cm/s^2 and 33.5 cm/s, respectively, and the duration of strong shaking is more than 20 seconds. A record with peak acceleration 922 cm/s^2 is also obtained at the ground floor of a building in the same site at a distance of about 20 m from the previous station. This site is located on the pleistocene terrace, which is considered to amplify the earthquake shaking in short period range resulting high peak value.

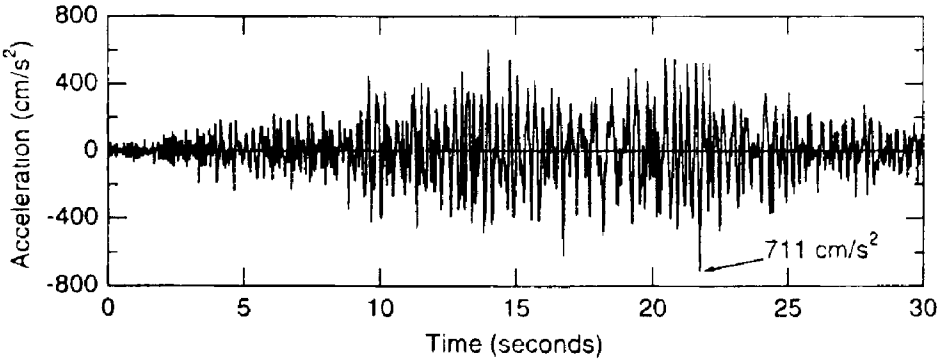

Fig.4 Time Record of Acceleration at Kushiro Meteorological Observatory[3]

Earthquake records at other stations in Kushiro City did not show such large peak values. The peak acceleration at Kushiro Port was 468 cm/s^2, at the Kushiro River Dike, 320 cm/s^2 and at Otanashike Bridge, 456 cm/s^2. No ground motions were recorded close to Midorigaoka. According to interviews with the residents, seismic intensity in Midorigaoka is estimated to be 5.4 to 5.7 in JMA intensity[3]

Figure 5 shows distribution of ground failures in Midorigaoka. A slope with a height of 11 m collapsed at site ① in the figure. A wooden house slipped down the slope and two houses were crushed by the collapsed soil as shown in Photo 2. Liquefaction effects such as sand boils and floating up of manholes were observed as well as ground cracks. Manholes floated up 5 to 20 cm at many sites. Sand boils were observed at fewer locations than would be expected because of the frozen layer of ground at the surface estimated to be 50–100 cm thick at the time of the earthquake.

Underground pipelines and foundations of wooden houses settled differentially and were displaced laterally where the ground cracks were abundant. This implies that a large amount of permanent ground deformation occurred in these areas. The magnitudes of the vertical and horizontal ground displacements were estimated to be in the range of approximately 30 to 50 cm on the basis of widths of ground cracks and displacements of pipelines and foundations of the houses.

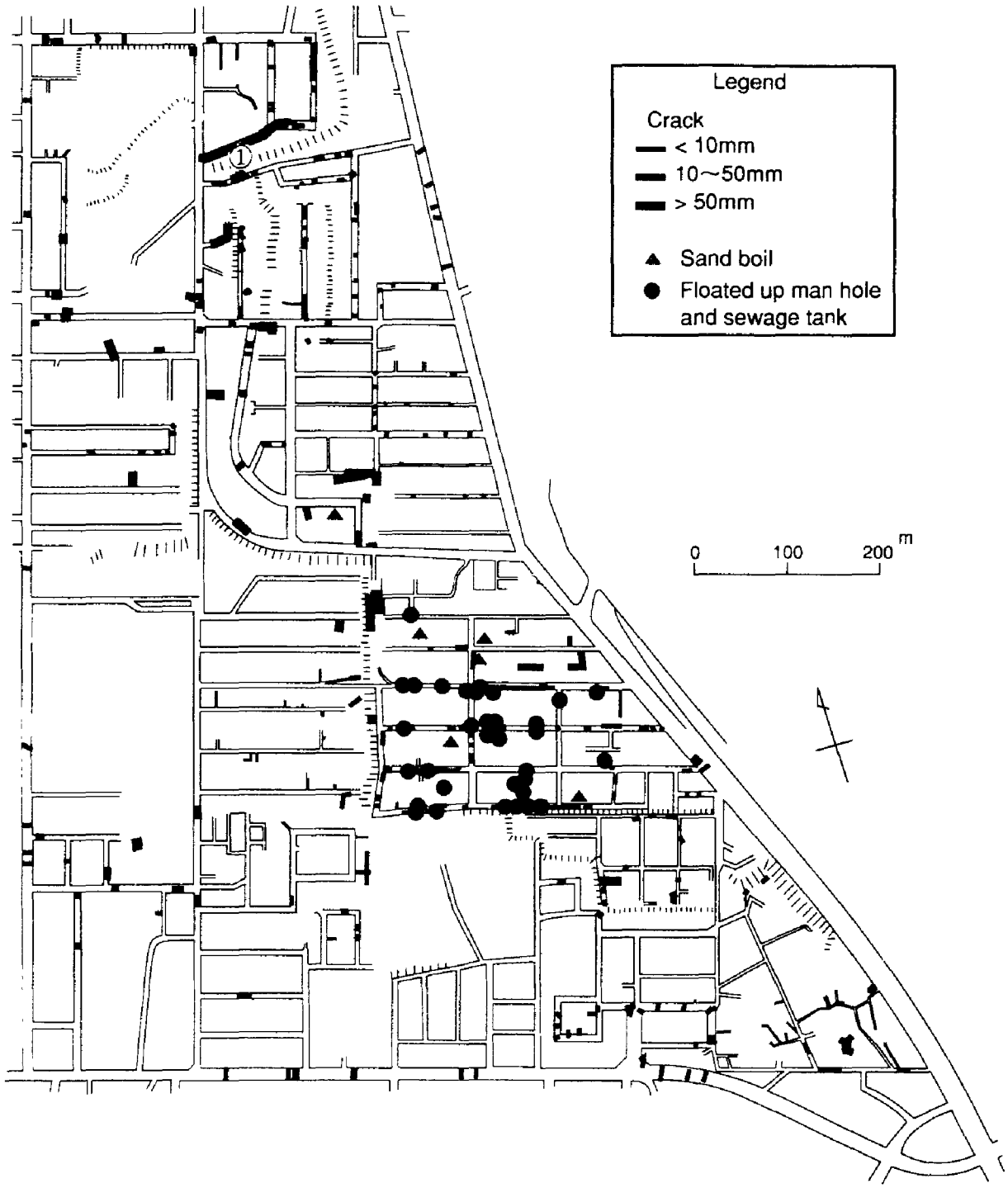

Fig.5 Map of Midorigaoka Showing Locations of Ground Failures and Floated up Manholes[2)]

Figure 6 is a comparison of the grain size distribution curves of sands from sand boil deposits at different locations in Midorigaoka and natural volcanic ash which is generally used as fill material in this area. Both soils have similar grain size characteristics, which implies that volcanic fills were liquefied during the earthquake, and may be natural material.

According to the residents, sand boils and ground cracks were also observed at the time of the 1973 Nemuro-hanto-oki earthquake at the same locations. This indicates reliquefaction at the same sites.

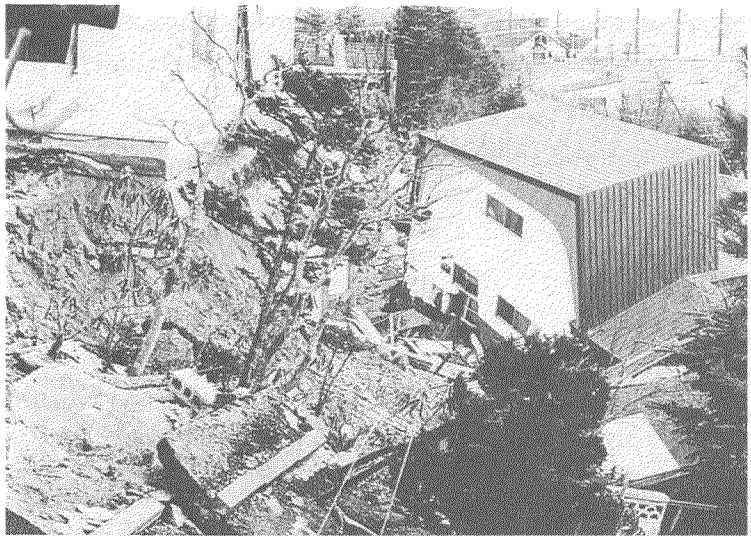

Photo 2 Slipping Down of a Houses due to Slope Failure
(Courtesy of Kiso-jiban Consultants Co.)

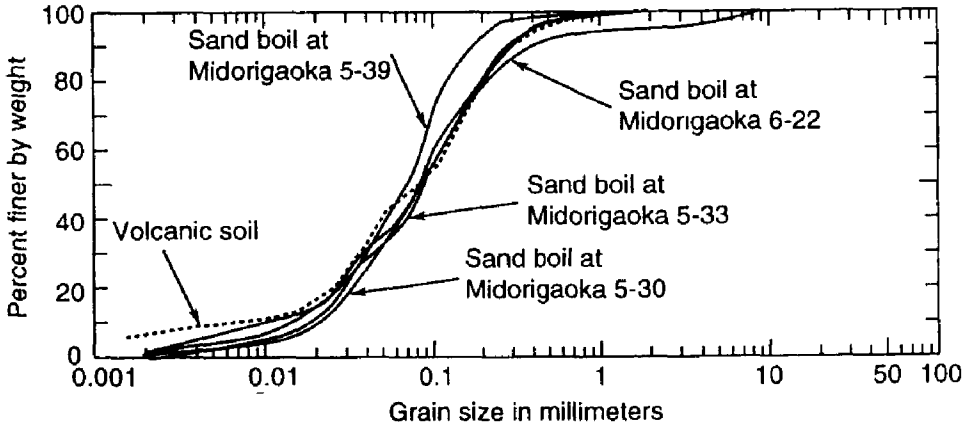

Fig.6 Grain Size Distribution Curves for Volcanic Ash Used as Fill Material[2] and Sands Collected from Sand Boils in Midorigaoka

DAMAGE TO STRUCTURES

Water Supply Lifelines

There are approximately 671,318 m of pipelines in Kushiro City. Main distribution lines are of four types: ductile iron pipe (DIP) with mechanical or push on joints, polyethylene pipe (PP) with coupling joint, gray cast iron pipe (CIP) with socket and spigot joint, and asbestos cement pipe (ACP) with coupling joint. Pipe diameters are 40, 50, 75, 100, 150, 200 and 500 mm. Local service pipes are of three types, PP, CIP and ACP with diameters 13, 20, 25, 50, 75, 100 and 150 mm. All pipelines are buried with a nominal depths of cover greater than 1.6 m.

There was damage at 2 locations in the main water distribution system and at 9 locations in the local service system in Midorigaoka. This is approximately one-third of entire damage in Kushiro City to water supply system. Figure 7 shows the locations, types and diameter of damaged pipes, and damage modes of both main distribution and local pipelines. The pipe and joint damage occurred only in the areas of ground failures shown in Fig.5 in Midorigaoka.

Wastewater Lifelines

There are 947.5 km of wastewater pipelines in Kushiro City ranging in diameter from 200 to 1,000 mm. They consist of vinyl chloride pipes (VCP) and centrifugally compacted reinforced concrete pipes (RCP) with rubber joint. In total 47 sites, 7,744 m of the pipes, were damaged due to the earthquake. Figure 8 shows the locations, types, diameters and lengths of damaged pipes. At the damage locations the pipes buried at a depth of 3.4 m on average and supported by timber piles or macadam. Damage was primarily in the form of floating and settlement of the pipelines due to the displacement of the joints, round cracks of pipes and manholes, pull-out or break of joints, and floating of manholes as shown in Photos 3 and 4. The amount of both floating and settlement of pipelines were ranged from several cm to several ten cm.

Gas Distribution Lifeline

The gas distribution and local service pipelines in Midorigaoka are comprised mostly of steel pipes and some polyethylene pipes, which buried at cover depths of about 1.0 – 1.2 m. Small diameter pipes of 25, 30 and 50 mm were built with threaded joints, whereas large diameter pipes of 100, 150 and 200 mm were built with welded and A-II type mechanical joints. Figure 9 shows the locations of damage to mains and branches of high and low pressure gas distribution lines. All of the damage was occurred at threaded and mechanical joints. No breaks or other damage to pipe with welded joints was reported.

Building

Most buildings in Midorigaoka were single family one- or two- story wooden houses,

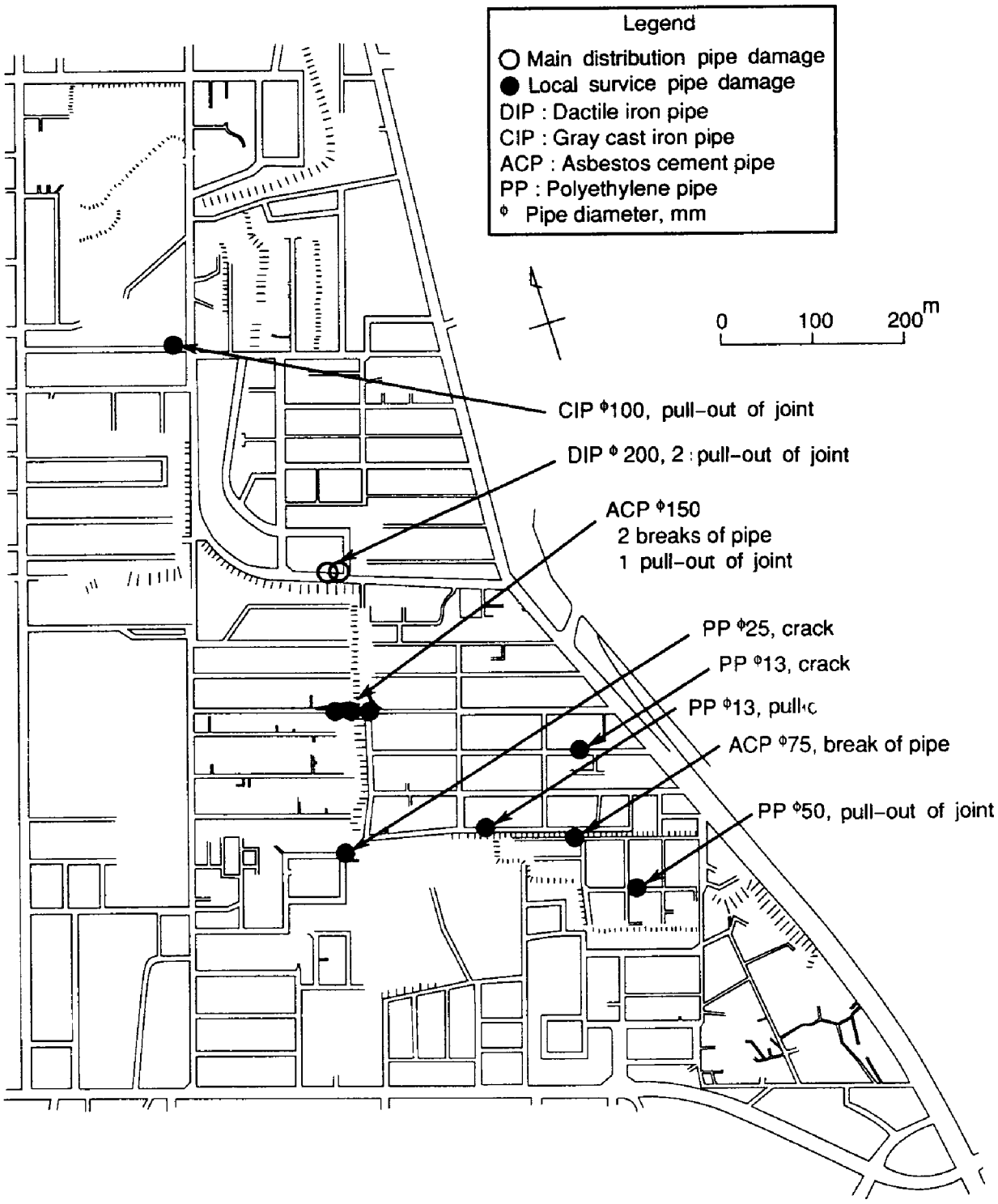

Fig.7 Map of Midorigaoka Showing Locations of Damage to Water Distribution and Survice Pipelines

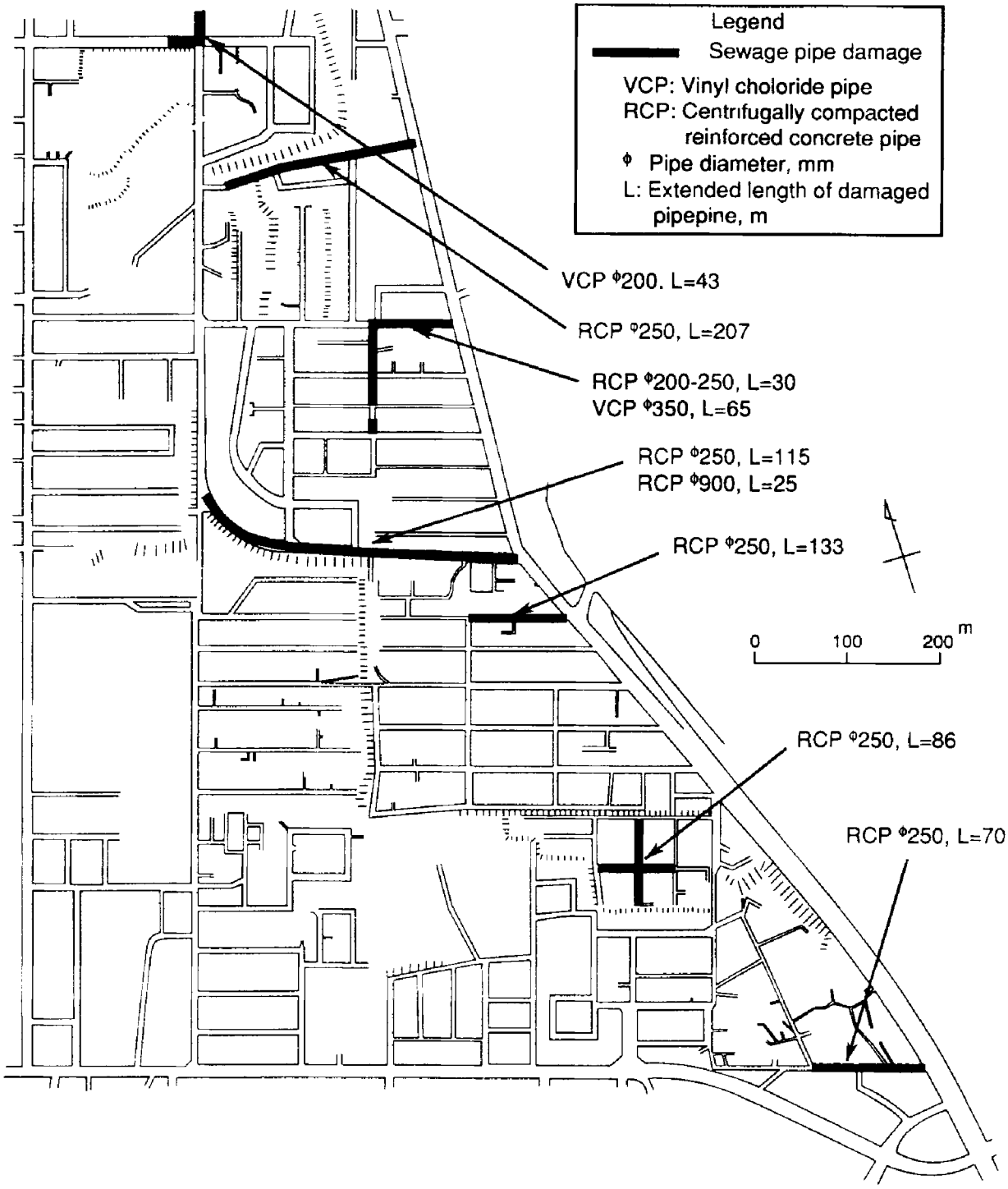

Fig.8 Map of Midorigaoka Showing Locations of Damage to Wastewater Pipelines