Land subsidence, or land-surface sinking, has become a major man-induced hazard in many parts of the world—including here in Venice. Many of the subsiding areas have become known only in recent years, and have taken place primarily since World War II as a result of the rapidly increasing population and industry. Man's continuing development of ground water, gas, oil, and minerals has been changing the natural fluid regime in the subsurface at many locations throughout the world. Unfortunately, most planners of industrial complexes, urban developments, and water supply systems are not adequately informed about the potential hazards, costs, and the socio-economic and environmental problems that can result from land subsidence.

Subsidence can result from the compaction of sediments due to heavy withdrawal of water, oil, or gas and extraction of solids through mining, by the shrinkage and oxidation of organic deposits, the withdrawal of fluids for geothermal power, and the collapse of sediments contained in karst terrain. Many areas of subsidence are known, some having subsided as much as 10 m. Many more areas are likely to develop in the next few decades as a result of accelerated exploitation of natural resources, especially ground water, in order to meet the demands of the increasing population and industrial concentrations throughout the world.

Most areas of known subsidence are along coasts where the land sinking becomes quite obvious as the ocean or lake waters gradually creep higher and higher up the shore. The program for this symposium will show that flooding of populated and industrialized areas is a major problem resulting from subsidence of coastal areas at Tokyo, Japan; Houston, Texas, USA; Shanghai, China; Bangkok, Thailand; and Long Beach, California, USA. Estimates of the costs of damage or of remedial measures will be shown to be in the billions of dollars. Such subsided areas—Tokyo is an example—frequently must be protected from flooding as much as several meters by construction of extensive systems of dikes, flood walls, locks, and pumping stations. Other papers will show that changing gradients due to subsidence can seriously affect the capacity or drainage pattern of canals, drains, sewers, and streams. Structural failure of buildings, pipe lines, railroads, and other engineering structures at the land surface has occurred in some areas due to the slow tensional or compressional stresses caused by flexure of the sediments or due to the sudden, calamitous collapse of sink holes in karst areas. Compressional or shear failures of oil, gas, or water-well casings also occur frequently.

Subsidence due to ground-water withdrawal will be seen to range from about several hundred millimeters in Venice to about 10 meters in Mexico City, Mexico and the San Joaquin Valley, California to 15 meters in the Cheshire District of Great Britain, where rock salt has been mined by solution since Roman times. The areal extent of reported subsidence world wide is reported to range from 10 square kilometers in the San Jacinto Valley to 14,000 square kilometers in the San Joaquin Valley, both in California.

Other than with karst sink-hole conditions, subsidence usually is a subtle phenomenon. Despite the often large areal extent, the rate of
subsidence may be relatively slow and so widespread that the problem is not readily evident until underground pipelines crack, well casings buckle, or shorelines are flooded. With modern technology, such as fluid injection to replace withdrawn water or oil, it is reported that subsidence can be slowed or stopped. However, it should be noted that subsidence is essentially permanent. There is no known method at present for raising the land surface back to its former elevation, although a small island in the lagoon of Venice has been raised above flood level by high pressure injection of fluid grout.

More information on subsidence is available in a new UNESCO publication. Dr. Joseph F. Poland chaired an UNESCO/IHP Working Group on Land Subsidence, which consisted additionally of Laura Carbognin of Italy, Soki Yamamoto of Japan, German Figueroa Vega of Mexico, and me from the USA. The working group's purpose was to put our collective information and knowledge together into a publication entitled "UNESCO Guidebook to Studies of Land Subsidence Due to Ground-Water Withdrawal." This 327-page volume can be ordered from UNESCO in Paris, or its publishing outlets in many countries.

In conclusion, our Symposium Organizing Committee hopes this Third International Symposium will provide a good forum for the sharing of useful ideas and experiences. It is fervently hoped that this symposium and the subsequent proceedings will bring to the attention of planners, developers, and politicians, as well as other scientists, what might be called "man's participation in a natural hazard--land subsidence."

I now open the technical paper sessions of the Third International Symposium on Land Subsidence. As the first step, I will read the following citation in honor of Dr. Joseph F. Poland, to whom this symposium and subsequent proceedings are dedicated, in recognition of his world-renowned work in land subsidence and his long role as the Father of Land Subsidence Hydrology.

Citation

Dr. Joseph F. Poland received his A.B. in geology from Harvard University, and M.A. in geology and Ph.D. in hydrogeology from Stanford University. For 10 years prior to joining the U.S. Geological Survey, Dr. Poland worked as a geologist with an oil company in South America, taught at Stanford University, and consulted in the southwestern United States on geologic and hydrologic problems related to ground-water development.

Dr. Poland began his distinguished career with the U.S. Geological Survey in 1940 as geologist assigned to complex investigations of geology, hydrology, and geochemistry of ground waters beneath the Los Angeles coastal plain. In 1946 he was placed in charge of the state-wide ground-water investigations and associated research programs in California. His leadership during that assignment led to the delineation of the major aquifer systems and their storage capacity which proved to be so essential to the development of the world's largest and most expensive water development project—the California Water Plan.

From 1956 to his recent retirement, Dr. Poland was responsible for planning and carrying out fundamental research related to land subsidence and associated studies in the mechanics of aquifer systems. This research led to the saving of millions of dollars of irrigation, aqueduct, and highway construction costs in areas of potential subsidence in California.

Dr. Poland developed an international reputation of renown in his field. He has been called in as an expert consultant in many parts of the U.S. and internationally by organizations such as UN, UNESCO, and FAO. He served as the Chairman of the UNESCO Working Group on Land Subsidence, which has produced the UNESCO Guidebook to Studies of Land Subsidence Due to Ground—
water Withdrawal. He is a registered Geologist and certified Engineering Geologist in California. He has been active on many inter-agency committees and on organizing committees for international symposia and workshops. In 1968 he received the Department of the Interior's Distinguished Service Award for his outstanding scientific achievements, and in 1970 he received the Association of Engineering Geologist's Clair P. Holdredge Award for a paper considered an outstanding contribution to the profession of engineering geology.

Dr. Poland has authored more than 50 important scientific papers and reports on geohydrology, subsidence, geochemistry, mechanics of aquifers, and related aspects of hydrology.

By personal example, Dr. Poland has provided noteworthy leadership and has stimulated the flow of ideas and production of scientific contributions of co-workers. He particularly motivated the younger geologists and engineers with whom he worked during his 40-year career with the U.S. Geological Survey and is highly revered by such colleagues today, not only as an outstanding scientist but as a gentleman and a friend.

Dr. Poland's stature and reputation as a scientist, nationally and internationally, are outstanding. In recognition of his many achievements, the Proceedings of the Third International Symposium on Land Subsidence is dedicated to Dr. Joseph F. Poland.

Complimenting Dr. Joseph F. Poland (center) on his citation for outstanding achievement in land subsidence research is A. Ivan Johnson (right) Symposium General Co-chairman. Looking on with pleasure is Dr. Poland's wife, Eleanor (left).