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NEWS from Geothermal Subsidence Research Management Program

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This is the first edition of *News from Geothermal Subsidence Research Management Program*. The purpose of this publication, which we plan to issue at regular intervals, is to distribute information about developments in the Geothermal Subsidence Research Program.

GEOTHERMAL SUBSIDENCE RESEARCH PROGRAM.

A major consequence of development of a geothermal reservoir may be subsidence occurring due to withdrawal of voluminous amounts of fluids. Unexpected and uncontrolled subsidence can have detrimental social, environmental, and economic impact. In order to better understand subsidence, its causes and effects, the Geothermal Subsidence Research Program (GSRP) was initiated.

The goals of the GSRP are to develop methods for assessing naturally occurring subsidence, for inferring a geothermal reservoir's compaction potential, and for minimizing potential subsidence effects during exploitation of a geothermal reservoir. Attainment of these goals is expected to provide the tools needed for geothermal developers to measure subsidence and to predict the subsidence potential of a reservoir. For regulatory agencies, the program is expected to provide guidance with which to recommend appropriate action to minimize the impact of subsidence.

The GSRP is organized into four independent elements:

1. Subsidence Characterization - Subsidence characterization is concerned with studying examples of subsidence and subsidence effects. Research has been conducted to document cases of known subsidence in geographic areas having geological and physical environments representative of geothermal areas. Where data were available, i.e., Wairakei, New Zealand, and The Geysers, California, case histories have been written. Associated studies have also been conducted on the economic and environmental impact of subsidence. These studies indicated that there is an inadequacy of the latter date.

2. Subsidence Mensuration - Research has developed guidelines for surface monitoring surveys to establish background deformation rates and monitor possible deformation induced by geothermal development. Research to date

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also assessed the state-of-the-art of well bore extensometers to directly measure vertical distances between points in the wellbore. Several suggestions for improved instrumentation that have resulted from this research will make substantial contributions toward creating direct measurement instrumentation for use in geothermal wells.
Indirect measurement methods, i.e., gravity, resistivity and micro-seismic,have promise as inexpensive, areal survey techniques. Research will be conducted to evaluate the ability of these methods to detect changes in the physical properties of a geothermal reservoir, and to relate these changes to reservoir compaction and subsidence.

3. Subsidence Prediction - Ultimately, the ability to predict subsidence is dependent upon an understanding of the response of geologic materials and systems to natural and man-made stress fields. To gain this understanding, the Geothermal Subsidence Research Program has initiated research to study the response of reservoir material to various stress field changes.

   Other research will assess various subsidence models, review their relative analytical merits, and, if necessary, make recommendations for new models. A related project will develop methods for physical modeling using a centrifuge. Predictions of subsidence made by numerical modeling can thus be evaluated by comparison with a centrifuge model.

   Out of these efforts may evolve better understanding of how geologic materials and systems respond to stress field changes, and enable earth scientists to more accurately predict subsidence over a given reservoir. A step toward greater predictive capability is the assessment of existing theory and its applicability to geothermal reservoirs. Most subsidence theories were developed to describe the compaction of oil and gas reservoirs or of relatively shallow unconsolidated aquifers.The applicability of these theories to deep, thermodynamically complex geothermal systems needs to be examined.

4. Reservoir Operating Policy - The final element in the GSRP is the development of policies that minimize the effects of subsidence. These policies are derived from the research results of the previous three elements and should provide regulators and developers with:

   (a) the ability to distinguish naturally occurring subsidence from that possibly caused by geothermal operations, and

   (b) the basis to operate or control a geothermal field such that adverse subsidence effects are minimized or avoided.

The Subsidence Program is sponsored by the U.S. Department of Energy, Division of Geothermal Energy, and administered by Lawrence Berkeley Laboratory. At LBL the project manager for this work is Dr. John H. Howard; the program manager is Werner J. Schwarz, John E. Noble is the technical program manager, and Terry Simkin the senior advisor. The principal advisor for GSRP is Dr. Paul A. Witherspoon, Associate Director of LBL and Head of the Earth Sciences Division.

PROGRAM STATUS

Contracts completed in FY'78:

- Case Histories

  Four case histories were completed by Systems Control, Inc. in the following areas: Wairakei, New Zealand; Chocolate Bayou, Texas; Geysers, California; and Raft River, Idaho. The four subsidence sites were selected on the basis of: (1) physical relevance of subsidence areas to high priority U.S. geothermal sites in terms of withdrawn geofluid type, reservoir depth, reservoir geology and rock characteristics, and overburden characteristics, and (2) data completeness, quality and availability.

  These case histories can serve as models for developers and/or regulators in assessing the subsidence potential for their area of interest.

- Environmental and Economic Effects

  A contract with EDAW/Earth Sciences Associates resulted in assessment of data available from areas have experienced geothermal and non-geothermal subsidence. A detailed appraisal was made of areas with the most comprehensive data base. Areas studied included desert basins in central and southern Arizona; Baldwin Hills and Inglewood, California; Galveston, Texas; Las Vegas Valley, Nevada; Mexico City, Mexico; San Joaquin Valley, California; Santa Clara Valley, California; Wairakei, New Zealand; and Wilmington Beach, California.

  The quantity and quality of data collected for areas studied were disappointing; no comprehensive studies of the effects of subsidence were found for any of the areas, most cost data were based on estimates rather than actual expenditure records, and in general there was a lack of public awareness of subsidence except in areas where other hazards, i.e. flooding, were aggrevated.

  While there is a serious lack of reliable data on direct effects of subsidence in the areas studied, it does appear possible to quantitatively predict many types subsidence effects using conventional engineering techniques to supplement the limited subsidence data.

- Surface Monitoring - Guidelines Manual

  A geothermal development program must include monitoring of horizontal and vertical displacements at the surface and at depth before and during production. It should be possible to differentiate between subsidence caused by geothermal operations and that caused by other man-induced activities, or those occurring naturally.

  Woodward-Clyde Consultants has produced a manual that reviews various surface monitoring methods and compares their installation, utilization, and accuracy. Utilization of these methods should enable planners and regulators to determine the natural rate of subsidence. In addition, such a manual can be used to ascertain induced subsidence during development and production of a geothermal field.

- Direct Measurements of Changes in Vertical Distances in a Wellbore.

  Another Woodward-Clyde Consultant study reviewed instruments available for monitoring wellbore displacements, both vertical and horizontal. Techniques and materials for improving or developing new instruments were evaluated. Elements of sensor and signal technology with potential for high temperature monitoring of vertical wellbore changes were identified.

  Woodward-Clyde has recommended hostile environment testing for the following four components: 1) induction coil with slip collar well casings, 2) reed switches with magnet emplaced in slip collars, 3) electromagnetic oscillators with magnets emplaced in slip collars, and 4) radioactive logging with tracers emplaced to either slip collar or directly into the formation.

Contracts in Progress:

Three contracts started in 1978 will be continued in 1979:

1) An assessment of existing mathematical subsidence and deformation models by Golder Assoc.; Seattle, Wash.

2) High temperature and high pressure compressibility studies of cores from geothermal reservoirs by Terra Tek, Inc.; Salt Lake City, Utah.

3) Centrifuge compaction studies of reservoir materials by Colorado School of Mines; Golden, Colorado.

Future Projects:

The program will initiate research in the following areas:

1) Supplemental Case History - Chocolate Bayou
   Objective: Expand the Chocolate Bayou Case Study in order to make the study more comprehensive. An expanded study could also be useful as a model to researchers at the Brazoria Geopressure field located south of the Chocolate Bayou field.

2) Subsurface Risk Assessment
   Objective: Analysis of subsurface damage caused by compaction. The magnitude of the economic loss caused by compaction could possibly exceed the surface loss caused by the related subsidence. The risk of subsurface damage must be considered in order to judge the full cost of any geothermal development.

3) Hostile Environment Tool Development
   Objective: The four suggestions for improved well bore extensometers made by Woodward-Clyde Consultants will be component tested.

4) Assessment of Radioactive Bullets
   Objective: Additional review of radioactive bullet logging will be made to assess the applicability of this technique to monitoring subsurface compaction.

5) Assessment of Indirect Techniques
Objective: Indirect measurement methods, i.e. gravity, resistivity and microseismicity, have promise as inexpensive, areal survey techniques. Reseach will be conducted to evaluate the ability of these methods to detect changes in the physical properties of a geothermal reservoir, and to relate these changes to reservoir compaction and subsidence.

6) Assessment of Physical Subsidence Theories
Objective: A step toward greater predictive capability is the assessment of existing subsidence theory and its applicability to geothermal reservoirs. Most subsidence theories were developed to describe the compaction of oil and gas reservoirs or of relatively shallow unconsolidated aquifers. The applicability of these theories to deep, thermodynamically complex geothermal systems will be examined.

7) Creep phenomena and inelasticity
Objective: Related to the assessment of existing subsidence theory is an assessment of rock creep and inelasticity at high temperature and high pressure. The effects of this phenomena are little understood and limit accuracy in predicting subsidence. Research will be conducted to study their contribution to compaction and subsidence.

Related Geothermal Programs

The GSRP is cooperating with the following programs:

Geothermal Logging Instrumentation Development Program
Sandia Laboratories

Environmental Impact Assessment of Geothermal Development
Lawrence Livermore Laboratory

USA/Mexico Cooperative Study of the Cerro Prieto Geothermal Reservoir
Lawrence Berkeley Laboratory

Susanville Geothermal Resource Assessment Program
Bureau of Rec. - City of Susanville, California

Induced Seismicity Program
DOE, Las Vegas, Nevada

Geopressured Geothermal Evaluation Program
DOE - University of Texas, Austin

Geothermal Research Program
US Geological Survey

RECENT MEETINGS

Geothermal Subsidence Research Program Workshop:

In October, 1978 a workshop was convened to review the results of completed research, assess the adequacy of the program plan, and make suggestions on revision of the original Geothermal Subsidence Research Program planning document (LBL-5983). The workshop provided to LBL management a timely review of the entire GSRP effort. A revised planning document will be issued in the near future.

PUBLICATIONS AND DOCUMENTS

The following publications will be available from the GSRP program office at LBL upon request:

Subsidence Series # 1 Environmental and Economic Effects of Subsidence (EDAW/ESA) LBL 8615

Subsidence Series # 2 Instruments for Subsurface Monitoring of Geothermal Subsidence (Woodward-Clyde Consultants) LBL 8616

Subsidence Series # 3 Guidelines Manual for Surface Monitoring of Geothermal Areas (Woodward-Clyde Consultants) LBL 8617

Subsidence Series # 4 Case Histories of Subsidence Areas (Systems Control, Inc.) LBL 8618

Geothermal Subsidence Research Program Program Summaries, ed. by Simkin, T., and Noble, J.E. (UCID 8035) July 1978

Geothermal Subsidence Program Plan LBL 5983, April 1977

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