Alaska Power Authority

SUSITNA HYDROELECTRIC PROJECT

PROPOSAL FOR

PLAN OF STUDY

JUNE 1979

Acres American Incorporated
900 Liberty Bank Building
Buffalo, N.Y. 14202

F&M Consultants Incorporated
5024 Cordova Street
Anchorage, AK 99503

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EARTHQUAKE ENGINEERING

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SUSITNA HYDROELECTRIC PROJECT

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SUPPLEMENTARY SUBMISSION -
EARTHQUAKE ENGINEERING

1. INTRODUCTION

This document is a supplementary submission to the Acres-R&M-Moulin-TES proposal to Alaska Power Authority for the Susitna Hydroelectric Project. The purpose of the submission is to provide additional demonstration of the capability of the ARMT group in earthquake engineering and design of major projects in seismically active areas. To strengthen the expertise available to the group in earthquake engineering, the support services of Woodward-Clyde Consultants Inc. have beer added to the group on a non-exclusive basis.

Section 2 of this submission deals with the capabilities of Acres in seismic work, Section 3 with R&M and Section 4 with Woodward-Clyde Consultants. These three members of the group bring to the Susitna Project a strong team of expertise jointly capable of handling all aspects of seismic design of major engineering structures, particularly in the Alaskan environment.

2. ACRES AMERICAN CAPABILITIES

Acres has been involved with several projects located in high-risk earthquake zones. Acres experience ranges from the collection of seismic data, statement of the problem, determination of earthquake effects on foundation materials and earth structures, laboratory testing of dynamic properties of the materials, and earthquake stability analysis both pseudostatic and dynamic for design of structures including dams, powerhouses, spillways and structural buildings. A few of the recent projects are outlined as follows.

KPONG HYDROELECTRIC PROJECT
GHANA

1976-presently under construction

Acres

Kpong Hydroelectric Project is located in a high earthquake risk zone. The project consists broadly of concrete structures, including a powerhouse, a spillway founded on bedrock, and an earth-fill dam and dikes approximately 4 miles long founded on floodplain soil deposits. A seismicity study was carried out by Acres which led to consideration of an earthquake with 0.25 g acceleration in design. Dynamic analysis using the response spectrum techniques was utilized to calculate seismic loads induced on the powerhouse and spillway structures.

The energy of design earthquake was accounted for in the stability analysis for the eartn structure by application of a constant horizontal acceleration to the critical static failure condition. The dikes are founded on floodplain deposits (approximately 12 m thick) consisting of silty clay underlain by loose sands. The foundation was analyzed for its susceptibility to liquefaction for postulated ground motion by calculation of cyclic shear stress ratio and correlating it to the relative density of underlying loose sands as determined from standard penetration resistance in several boreholes. The laboratory tests carried out on the foundation materials included triaxial load tests to simulate dynamic stress conditions.

GREAT CANADIAN OIL SANDS SLUDGE POND
FORT McMURRAY, ALBERTA

DYNAMIC TESTS AND
EARTHQUAKE ANALYSIS

1976

Acres

The study included establishing the ground motions which could be induced by an earthquake in the area and determination of time-dependent shearing stresses in a sludge pond under a random excitation produced by the earthquake. The variation of dynamic shear stresses within the sludge pond with depth by the earthquake against time was analyzed. The total height of the dike surrounding the pond was 250 ft.

The laboratory tests carried out to determine the dynamic properties of the sludge material included cyclic axial load tests to simulate dynamic stress conditions and determination of its susceptibility to failure and torsional vibration tests to measure its deformation modulus during dynamic loading.

IRAQ 400-kV SUPERGRID
IRAQ

1976-presently under construction

Acres Shawinigan Limited

The project involved the study of the seismicity of a transmission line route some 530 miles long and earthquake stability analysis for the design of transmission towers. The foundation conditions and earthquake loadings along the transmission route are highly variable, resulting in variable horizontal and vertical accelerations.

ACRES

BORUCA HYDROELECTRIC PROJECT
COSTA RICA

Presently under construction

SNC-Acres-TIL (Consortium)

Boruca Hydroelectric Project is located in a high earthquake risk zone in Costa Rica. The project consists of an 800-ft high rock-fill dam and concrete structures, including a powerhouse and a spillway. Woodward-Clyde consultants are involved with defining of the maximum credible earthquake and establishing of critical ground motion characteristics. The detailed analysis and evaluation for an earthquake is being studied by the consortium, comprising calculation of static stress in the embankment prior to the occurrence of an earthquake and of stresses induced due to postulated seismic event by linear finite elements method of analysis and further evaluation of the stability of the embankment during and at two selected time intervals after the postulated earthquake event. The seismic analysis carried out shall be reviewed by Dr. H. Seed and Dr. R. Peck.

ACRES

HOT SPRINGS, ARKANSAS
TAILINGS DISPOSAL DAM

Constructed 1977

Acres

The Hot Springs Tailings Dam Project involved the raising of an existing tailings dam to provide adequate pond storage capacity for maximum probable flood condition. Since the embankment is constructed primarily of mine tailings, an evaluation was made of the liquefaction potential of the dam during earthquake conditions.

This portion of the project consisted of determining the design earthquake and conducting careful standard penetration tests in the existing embankment to use in a corelation with the liquefaction potential using the method by Seed and Idriss (1971). A direct result of this analysis was to provide in the design provision for adequate internal drainage to provide greater effective overburden stress and thus reduce liquefaction potential under the design earthquake. Stability analysis of the dam was conducted using pseudostatic analysis.

ACRES

URAVAN, COLORADO
TAILINGS DISPOSAL EMBANKMENTS

Currently in progress

Acres

A study is being conducted of the Uravan tailings disposal sites which consist of existing tailings piles to heights of over 150 feet to ultimately determine means of stabilizing the piles under earthquake loading. A probabilistic approach to earthquake magnitude has been conducted by others and these design values will be utilized to perform stability analysis of the tailings embankments.

3. R&M CONSULTANTS CAPABILITIES

Southern Alaska is in one of the world's most active seismic regions. Large earthquakes are common. For example, the largest recorded earthquake in North America, the Great Alaska Earthquake of 1964 with a magnitude of 8.4-8.5, was centered in the Prince William Sound area of Southcentral Alaska. Property damage and visible ground movement were extensive over a large area of the state.

Due to the potential occurrence of large magnitude earthquakes in southern Alaska, seismic analyses must be included in engineering studies and designs for many major facilities. R&M Consultants, Inc., has performed several detailed seismic analyses for a variety of projects. Analyses have varied in detail from seismological interpretation to prediction of ground response for various earthquake magnitudes and structural response spectrum analysis. Special foundation designs are commonly recommended based on this design data. A representative listing of projects on which R&M has performed varying degrees of both static and dynamic seismic analysis includes the following:

Lake Otis Hospital; Anchorage, Alaska.

Peterson Towers (high rise office building); Anchorage, Alaska.

Alaska Pioneer Homes; Juneau ! Anchorage, Alaska.

Geologic Materials and Hazards Analysis, Proposed New Capital Site; Willow, Alaska.

Rockslope Design, Dewatering, Reinforcement, Valdez Pipeline Terminal; Valdez, Alaska.

Saxman Dam (concrete-face, rockfill); Ketchikan, Alaska.

Municipal Light and Power 115 KV Switchyards; Anchorage, Alaska.

Seismic Risk Analysis, Seward Marine Shore Station; Seward, Alaska.

Involvements on this varied project profile have demonstrated R&M's capabilities to extend state-of-the-art approaches through innovative design solutions. For example, at the Seward Marine Shore Station a probability study of seismic risk for permanent slope displacement was provided, and as a portion of the design package for the Municipality's 115 KV switchyards, a response spectra analysis was prepared. This analysis has been incorporated into a set of seismic design criteria for the Municipality's future use. Continued R&M involvement with the geotechnical engineering efforts for the Northwest Alaskan Gas Pipeline has kept the company abreast of new seismic analysis developments and applications.

For the Valdez pipeline terminal, R&M provided a resident geologist who engaged in full-time consulting services for a period of three years. Activities began with geologic investigation of bedrock conditions by surface mapping and subsurface drilling and coring of bedrock. This

geotechnical data was then used in the design effort to produce an extremely conservative design for the rockslopes and their reinforcement, such that the rockslopes would be stable during the design contingency earthquake (0.6 g lateral acceleration). A conservative design was required because of the height of the rockslopes (up to 230 feet) and their proximity to vital facilities of the terminal complex.

For the proposed new State Capital at Willow, the field investigation, performed for the Capital Site Planning commission, was part of an investigation which applied the techniques of terrain unit analysis to a 100 square mile area. These procedures allowed the collection of considerable geotechnical data to be used for environmental assessment of the Capital Site for evaluation of geologic materials hazards. A final derivative map was developed to describe the type and severity of various geologic hazards. Hazards documented included permafrost thaw-settlement, settlement, slope stability, seismic ground shaking, seismic ground fracturing, and seismic liquefaction. The ground fracturing hazard is related to the Castle Mountain Fault in the area near the Little Susitna River at the east end of the capital site. A statistical study of the seismicity of the capital site was performed and the frequency of occurrence of earthquakes of various magnitudes was also predicted. One conclusion reached was that the capital site is in a somewhat less seismically active area than either Fairbanks or Anchorage.

4. WOODWARD-CLYDE CONSULTANTS CAPABILITIES

Woodward-Clyde Consultants has been operating in Alaska for over ten years and have amassed a considerable data base on geological and geotechnical conditions, faulting and seismicity of the Anchorage and rail-belt areas. The data base has been developed from several major faulting studies, seismicity evaluation of large areas of Alaska, major geological and geotechnical participation on the trans-Alaska pipeline and the proposed northwest gas pipeline, and four site specific studies.

In addition, Woodward-Clyde bring to the Susitna Project considerable seismic and earthquake engineering expertise in connection with major dam and power projects in seismically active areas. The Woodward-Clyde team will be led by Dr. Don Tocher, a leading authority on the seismic safety aspects of sites for large engineered structures.

Brief descriptions of some Alaskan projects involving earthquake engineering recently undertaken by WCC are presented on the following pages, together with resumes of key WCC personnel.

ALYESKA PIPELINE EXPERIENCE

Project: Trans-Alaska Oil Pipeline System

Client: Alyeska Pipeline Service Company

Location: Prudhoe Bay to Valdez, Alaska

Assignment: Geotechnical Engineering Consulting Services

General Statement - Woodward-Clyde Consultant personnel participated very widely in the extensive geotechnical engineering effort associated with the trans-Alaska pipeline project. Our involvement covered

- the early conceptual studies and government submittals
- the main design phase
- the preconstruction and construction phases
- preparation for pipeline operation.

From February of 1971 to April of 1978, we provided personnel working hand-in-hand with Alyeska personnel on engineering tasks. Additionally, personnel located in our offices performed on many specific tasks or projects such as the VSM tests and the earthquake fault studies. All along we made laboratory tests on soil samples shipped from Alaska to our Oakland, California soils laboratory.

Throughout this period we also participated with Alyeska in preparing documentation for submittals and presentations to, and discussions with, government review personnel.

The major identifiable technical tasks performed by WCC personnel fall in the following categories:

- geotechnical data gathering
- pipeline construction mode and design aspects
- VSM field tests
- earthquake fault studies
- participation in pipeline construction
- preparation for pipeline operation

In addition to accomplishing these specific tasks, senior WCC personnel also contributed significant concepts and ideas that established direction for the project in the engineering, engineering-management and government-relations fields. Several such contributions are outlined in a later section, following the discussions of the specific technical tasks.

Geotechnical Data Collection

Soil Exploration - We participated in planning soil and geotechnical exploration programs. During the field exploration, WCC personnel technically

evaluated drilling and sampling methods to provide for efficient field operation. At Valdez we made an offshore subsoil investigation utilizing a vibratory core sampler in support of the design of the ballast water outfall.

Laboratory Testing - In support of the design work, we conducted several laboratory test programs on samples recovered along the pipeline. These included tests to determine thaw strain due to thawing of initially frozen samples and the shear strength of initially frozen soil samples during and after thaw; the load-displacement-time (creep) behavior of frozen samples at controlled temperatures just below 32°F; the permeability to hot oil of compacted glacial till samples with and without bentonite admixture; and the thermal energy content (unfrozen moisture content) of frozen samples. Several of these testing programs were without precedent and required design of test equipment and development of test and analysis techniques.

Pipeline Design Aspects

Thaw Plug Stability - We investigated the "thaw plug" stability along the pipeline, i.e., the stability of the zone surrounding the buried pipeline or underlying the workpad of the elevated pipeline which is subject to thawing. We established design criteria for thaw plug stability, including consideration of earthquake forces, and made mile-by-mile evaluations for it. The results of this evaluation impacted on construction mode selection. An extensive program of field measurement of pore pressures and shear strengths in developing thaw bulbs complemented this effort.

Thaw Settlement - We participated in evaluation of methods to determine thaw settlement of thawing soils based on extensive thaw strain tests, and made mile-by-mile thaw settlement evaluations for use in determining construction modes.

Construction Mode Selection - For the most part, geotechnical considerations governed the selection of construction modes - conventionally buried, specially buried, and elevated on VSM bents. We participated in this selection both in preliminary studies and in detailed mile-by-mile evaluations.

Buried Pipeline Design - We investigated soil restraining characteristics (lateral and longitudinal) for bends and straight sections of buried pipeline, for both conventional and special burial. We also generated mile-by-mile geotechnical parameters for use in buried pipeline design, and evaluated foundation design for buried mainline valves.

Elevated Pipeline Design - WCC personnel had major responsibility in developing the types of VSM used for support of elevated sections of the line, in developing design criteria for these supports, and in generating mile-by-mile geotechnical information for use in mile-by-mile VSM design. This work was based in large part on the VSM field tests described later. A computer system to design each pile along the pipeline alignment was developed under the technical management of Woodward-Clyde personnel. The system was designed such that new pile designs for above ground pipeline sections could be generated rapidly if field conditions were found to be different during construction than

assumed during design. The loadings for the piles were taken from an existing program which produced the mile-by-mile design for the above-ground pipe accounting for thermal and structural loads.

As Built Data - Following up the design, computer systems were developed that recorded "as-built" pile data, materials used, and other related data. Also a system was set up to record and aid in evaluation of data generated during the hydrotesting that preceded the operational loading of the pipeline.

Pipeline Bridges - WCC personnel has major responsibility during the field investigation, design and construction of the foundations for all pipeline bridges except the Yukon River Bridge.

Remote Valve Sites - We developed foundation recommendations for the equipment building and propane tanks at all remote gate valve sites.

Construction Zone Design - WCC personnel participated in developing initial criteria for construction zone grading; i.e., need for and extent and details of grading, and determination of cut and fill slopes for different thawed or frozen materials. Individual cases of grading problems were evaluated and resolved.

VSM Field Tests

WCC personnel had responsible control of three generations of VSM field tests for the project. The first set of tests, conducted in 1970, resulted in initial design criteria, but also demonstrated that driven VSM without thermal protection would need to be unreasonably long. The second set of tests, in 1972, resulted in second-generation criteria and indicated the superiority of installing VSM in oversized predrilled holes and slurrying the annulus. The third set of VSM tests, in 1975, confirmed the tentatively adopted design criteria for thermal VSM in different soil types. The three sets of tests were instrumental in the evolution of VSM types and design criteria for the project, and resulted in the finally adopted design. WCC also participated in planning and documentation of other field VSM load tests made during construction, and supervised laboratory VSM load tests at the University of Illinois.

Earthquake Fault Studies

WCC geologists conducted a detailed study of potential active fault displacements along the pipeline route. This study permitted the pipeline designers to minimize the risk from possible future surface faulting, by delineating potentially active faults, estimating the "design" fault motions, and thus permitting specific pipeline design for these motions. Aerial reconnaissance and detailed analysis of aerial photographs were used to locate all linear features or lineaments which might be potentially active faults. Photo-geologic interpretation included the use of Earth Resources Technology Satellite (ERTS) imagery, radar imagery and special low sun angle photography in selected locations. A later fault evaluation along the alignment of the suspected Clearwater Lake fault permitted elimination of any special design provision in this area.

Participation in Pipeline Construction

Preparation of Field Design Change Manual - WCC personnel generated the concept of the Field Design Change Manuals (FDCM) and prepared several drafts of both Volume I for VSM Construction and Volume II for belowground construction.

Field Engineering - WCC provided personnel for different field engineering functions, ranging from VSM hole logging to field engineering supervisor. In these capacities the personnel participated in all levels of field engineering work and decision making on pipeline construction. The work of the field engineers included inspecting construction, instructing the contractor, design change implementation and field documentation.

Office Support for Field Engineering - All through construction, WCC personnel were involved in office support of field engineering activities, including review of design changes, documentation, government interface, special field studies, and so forth. The fields for which WCC personnel took major responsibility included all aspects of VSM construction, belowground pipeline construction, and pipeline bridge foundations. For VSM in particular, there was further development of geotechnical design criteria, work on lateral load criteria, updating mile-by-mile design, and assistance to field engineers in solving VSM installation problems. For belowground construction there was review of bend design and development of overfill concept for as-built bends with insufficient cover.

Valdez Terminal and RCA Communication Towers - We p[illegible]ield geotechnical engineering personnel for the Valdez Terminal and t[illegible] RCA [illegible]mmunication tower foundations. At Valdez we also participated in the evaluation of rock slope stability and embankment stability.

VSM Reliability Evaluation - The WCC Decision Analysis group made a fault tree analysis of the failure potential of elevated pipeline due to settlement of the VSM. The analysis showed extremely low probability of pipe wrinkling due to VSM settlement.

Preparation for Pipeline Operation

Surveillance and Monitoring Manual - In 1976 WCC personnel prepared a Geotechnical Surveillance and Monitoring Manual for the pipeline, pump stations and Valdez Terminal. This manual is being utilized by surveillance personnel.

Maintenance and Repair Manual - WCC personnel participated in preparing Maintenance and Repair Manuals for geotechnical aspects of both aboveground and belowground sections of the pipeline.

Major Concepts and Ideas

The previous paragraphs highlight the specific WCC accomplishments on the project. While these accomplishments were vital to the project, we believe that our contributions to the project in the form of concepts and ideas were just as significant. Several examples of these are presented below:

- A WCC team developed many of the concepts for pipe support in the early studies for the pipeline. These concepts form the basis for much of the stress analysis of the pipeline.

- We foresaw the need for a major field engineering and quality control effort and documented this with various memos to Alyeska. These memos developed into the organizational structure that was adopted and to the Field Design Change Manual, the concept of which was developed by WCC personnel

- WCC introduced the concept of the use of heat pipes for controlling degradation of the permafrost. The early concept was the use of heat pipes to permit burial of the pipe in high-ice-content soils. This concept did not work out, however, it progressed to the use of heat pipes in the VSM which became the basic design solution for the elevated pipeline.

- WCC promoted the concept of task-oriented organization rather than discipline-oriented organization resulting in a reorganization of the engineering effort which was successful in completing the design of the pipeline.

- WCC personnel developed the concept of prequalification of manufacturers of the heat pipe and pushed this concept through to successfully deliver heat pipes to the project to meet schedule needs.

- WCC personnel participated in developing many of the strategies that were adopted in developing the design and construction plan and securing approval from the Federal agencies. As a part of this effort, assistance was provided in detailed planning to support the strategies adopted.

Project: Proposed LNG Plant at Yakutat. Alaska

Client: Pacific Alaska LNG Co. and California Alaska LNG Co.

Location: Monti Bay - Yakutat, Alaska

Assignment: Prelimi ary Site Investigation

A preliminary study involving geology, seismology, geophysics, oceanography, and static and dynamic geotechnical engineering was performed on a 400-acre site and the surrounding area to determine the feasibility for a major plant site. The site is located on a terminal moraine underlain by outwash deposits. Major faults with a history of major earthquakes lie within a radius of 50 miles from the site. Tsunami effects have been recorded. Sufficient information was developed to warrant continued consideration of the site for the plant location.

Offshore Geophysics - Boomer, Sparker and Sidescan Sonar surveys were conducted over approximately 2.5 square miles of the bay to develop bathymetry, estimate thicknesses of various subsurface strata and to idertify shoals or other shipping obstructions.

Geology and Seismology Studies - Using existing data and field reconnaissance, the geologic and seismic regimes which would constrain the use of the site were evaluated. Preliminary design earthquakes were established and tsunami and land level change potentials estimated.

Earthquake Engineering - Available data were analyzed in conjunction with the preliminary design earthquakes to develop preliminary design response spectra and to evaluate the potential for ground instability such as liquefaction or spreading. Bluff stability at the shoreline was also evaluated.

Foundation Engineering - Soil data were evaluated to establish preliminary design parameters for plant foundations.

Site Selection - Using results of the geophysical, geologic, seismologic, earthquake engineering and foundation engineering studies together with economic studies of grading and pier costs, recommendations were made as to the most suitable location of the plant within the site area.

Project: Proposed Northwest Alaskan Gas Pipeline

Client: Northwest Alaskan Pipeline Company, and Fluor Engineers and Constructors, Inc.

Location: Prudhoe Bay to Alaska/Yukon Border

Assignment: Geotechnical Engineering Consulting Services

Since 1977 Woodward-Clyde Consultants has been assisting the Northwest Alaskan Pipeline Company in their geotechnical efforts directed toward construction of the Alaskan portion of the Alaska Highway gas pipeline from Prudhoe Bay to the U. S. Midwest and West. Our work has included the following major tasks:

- Monitoring and evaluation of blasting tests
- Geotechnical and environmental data review
- Environmental review of access routes and realignments
- Fault study
- Laboratory testing of soil samples

These tasks are described in the following paragraphs.

Monitor and Evaluate Blast Tests

Woodward-Clyde Consultants monitored a series of trench blast tests conducted near Fairbanks, Alaska. The purpose of these tests was to demonstrate that effective trench blasting could be conducted very close to the trans-Alaska oil pipeline without generating damaging blast effects. At each of three test sites, geotechnical conditions were assessed using borings, trenches, aerial photography, geophysical techniques, and probings. Ground vibrations and air blast levels from each blast were monitored using seismographs to measure the particle velocities generated. The data generated were analyzed and presented in a detailed report which described all aspects of the tests, the data, and the theory to demonstrate that these blasts would not have significant impact on the oil pipeline. The report has been used by Northwest to demonstrate to the appropriate agencies that the Northwest construction blasting plans are credible.

Geotechnical and Environmental Data Review

Woodward-Clyde Consultants was retained to examine, catalog, describe, and evaluate existing data that could be used in the design of the Northwest Alaskan Gas Pipeline. This study covered open literature and proprietary data. In the open literature review technical publications, University of Alaska data, USGS information, Alaska Highway Department information and many other miscellaneous sources were examined and cataloged.

Proprietary data evaluated included the Canadian Arctic Gas files and the El Paso Natural Gas Company files relating to their efforts to bring Prudhoe Bay gas to the Continental U.S.

The final phase of this study was a review of the data generated by Alyeska Pipeline Service Company. The review included examination of the extensive data base, and appraisal of the validity and utility of the data to the gas pipeline project.

Environmental Review of Access Routes and Realignments

This project involved office and field investigations of access and alignments for the Delta Junction - Canada portion of the proposed gas pipeline. Biological, hydrologic, and land use evaluations were made. A preliminary office review of 250 access routes identified by Northwest was conducted using interpretation of aerial photographs (color 1:24,000), USGS topographic maps, marked alignment sheets, and literature available describing regional and local environmental characteristics. Based upon the results of our preliminary review, Northwest eliminated 51 routes from further consideration. The remaining 199 access routes were evaluated in the field in January 1978. Northwest used the evaluations to select environmentally suitable routes for its permit applications to State and Federal agencies.

Fault Study

This project identified candidate significant faults in the section of the gas pipeline between Delta Junction, Alaska, and the Alaskan-Canadian border. One objective of the study was to develop a definition of the term "significant fault" for the purpose of designing and constructing the pipeline. The study utilized existing seismographic records to identify microseismic clusters along the pipeline corridor, as these clusters may relate to faults. Geologic studies included extensive interpretations of aerial photographs and satellite images, and compilations of available geological data. A field reconnaissance of selected geological features of interest was included as part of the study. The results of the study were utilized to identify candidate significant faults and to assess the necessity of detailed field studies along these features.

Laboratory Testing of Soil Samples

The WCC Oakland laboratory conducted a massive laboratory testing program for the project, in support of the subsurface exploration program in the alignment section from Delta Junction to the Canadian border. The program included every-other-day pickup of samples along the alignment (a round trip of 750 to 800 miles out of Anchorage), an airlift of samples from Anchorage to San Francisco, and testing on a large scale in the Oakland laboratory. A total of about 1,500 samples from 150 borings were received; about two-thirds of the samples were frozen when they were recovered, and this frozen state was maintained from the recovery through shipment to Anchorage, San Francisco Airport and eventually to Oakland, where the samples were stored in a large freezing room. The large majority of the over 3,000 tests were index property tests, but a limited number of engineering property tests were also made.

Don Tocher

seismology
seismic geology
earthquake engineering

EDUCATION

University of California, Berkeley: Ph.D. Seismology, 1955
University of California, Berkeley: M.A. Seismology, 1952
University of California, Berkeley: B.A. Physics, 1945
Harvard University, Cambridge, Massachusetts: Undergraduate studies, 1942-1943

REGISTRATION

Geologist: California
Certified Engineering Geologist: California
Geophysicist: California

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, Principal and Chief Seismologist, 1974-date
University of California, Berkeley, Department of Geology and Geophysics, Seismographic Stations, Research Associate, 1964-date
United States Geological Survey, Earthquake Mechanism Laboratory, Geophysicist and Director, 1973-1974
National Oceanic and Atmospheric Administration, Earthquake Mechanism Laboratory, Geophysicist and Director, 1964-1973
University of California, Berkeley, Research Seismologist, 1956-1964
Harvard University, Cambridge, Massachusetts, Research Fellow, 1955

REPRESENTATIVE HISTORY

Since 1955, Dr. Tocher has been engaged in research and applications pertaining to the seismic safety aspects of the sites for large engineered structures, including dams, nuclear and conventional fueled power plants, offshore petroleum development projects and other structures.

Dr. Tocher has over 21 years of diversified scientific and supervisory experience in the seismological aspects of a wide variety of projects, both of a research nature and with applied engineering significance. He has been active in establishing programs for seismic monitoring of both natural earthquakes and large underground explosions, in such diverse parts of the world as Iran, the Middle East, Ecuador, Norway, Australia, Alaska, both on the mainland and in the Aleutian Islands, and at several locations throughout the United States. In a recent example, microseismic monitoring was conducted in the vicinity of three specific nuclear power plant sites in southern Iran, using a ten-station array of portable seismographs. This permitted a refinement of the interpretation of historic data and geologic field studies by defining limits of the zone of microearthquake activity.

More recently, Dr. Tocher has supervised the monitoring of aftershocks from the August, 1975 Oroville, California earthquake for the Pacific Gas and Electric Company, and devised a unique moving network survey of microearthquake activity along the Foothills fault system of California for the U. S. Bureau of Reclamation. These latter studies have made it possible to delineate the limits of the zones of activity, previously little known, as well as permitted determination of orientation of the stress axes producing the earthquakes.

Dr. Tocher's representative nuclear power plant siting projects include: plants at Hanford and Satsop (Washington); South Texas Project; three proposed sites in Oregon; proposed Skagit plant (Washington); Clinton (Illinois); Erie (Ohio); Davis-Besse (Ohio); Oyster Creek (New Jersey); Indian Point (New York); proposed Bodega Head plant (California); Humboldt Bay (California); San Onofre (California); proposed Vidal Junction plant (California); proposed Stanislaus plant (California); proposed plants at Torrente Saccione, Tarquinia, and Trino (Italy); sites near Bandar Abbas, Bandar Lengeh, and Kuyestak (Iran); Bushehr (Iran); Tsuruga (Japan).

Dr. Tocher has been involved in seismological research at the University of California, Berkeley, since 1956. During the years 1960 through 1963, he supervised the design, installation and operation of the world's first network of telemetered seismograph stations for microearthquake investigations. Subsequently, in 1964, he became Research Associate in the Seismographic Stations. Concurrent with this appointment and extending through 1974, Dr. Tocher was Geophysicist and Director of the Earthquake Mechanism Laboratory, initially under the U. S. Coast and Geodetic Survey, then the National Oceanic and Atmospheric Administration, and later under the United States Geological Survey. Previously, he was a Research Fellow at Harvard University.

Since 1955, Dr. Tocher has been a consultant on seismology to numerous public bodies and private corporations. He is currently a member of the International Union of Geodesy and Geophysics (IUGG) Committee on Natural Disasters; Chairman of the Earth Sciences Subcommittee of the Seismic Investigation and Hazards Survey Advisory Committee, City and County of San Francisco; a member of the International Association of Geodesy Commission on Recent Crustal Movements in the Pacific Region and in North America; and a member of the National Research Council, Division of Earth Sciences. In 1964, '66, and '68, Dr. Tocher was a delegate to the first, second, and third U. S.-Japan Conferences on Research Related to Earthquake Prediction Problems.

DT 5-78

During 1966-67, he was a member of the Ad Hoc Committee Advisory to the Secretary of Interior on Geologic Hazards Associated with a Site for a Large Nuclear Desalting Plant in Southern California. For IUGG, Dr. Tocher served as Seismology Representative on the Arrangement Committee for the 13th General Assembly and as a member of the Working Group for Seismic Scales. He was a member of the Committee on Earthquake Prediction, President's Office of Science and Technology; and is currently a member of the Panel on National Regional and Local Networks of the NAS-NRC Committee on Seismology. Dr. Tocher was scientific advisor to the United States Delegation, UNESCO Intergovernmental Conference on Seismology and Earthquake Engineering, Paris, 1964.

He has been a member of several other seismological committees, as well as a National Science Foundation - American Geological Institute visiting geoscientist to the University of Puget Sound and Western Washington State College, and a National Science Foundation - American Geophysical Union visiting geophysicist to Portland State University, and to the University of Montana.

AFFILIATIONS

American Association for the Advancement of Science
American Geophysical Union
Earthquake Engineering Research Institute
Explorers Club
Geological Society of America
Indian Society of Earthquake Technology
New Zealand Society for Earthquake Engineering
Royal Astronomical Society
Seismological Society of America
Society of Exploration Geophysicists

HONORS

University of California Distinguished Alumni Lecturer, Berkeley, 1973
Grove Karl Gilbert Award in Seismic Geology, Carnegie Institution of Washington, 1964
Harvard College National Scholar, 1942-43

PUBLICATIONS

Dr. Tocher's bibliography of publications includes more than sixty research papers in scientific journals. In addition, he chaired the committee responsible for compiling and editing the Seismology and Geodesy volume of The National Academy of Sciences - National Research Council Report on the 1964 Alaska Earthquake.

Woodward-Clyde Consultants

Ulrich Luscher

project management
geotechnical engineering
frozen soil engineering
performance and
instrumentation engineering

EDUCATION

Massachusetts Institute of Technology, Cambridge: Sc.D., Civil Engineering, 1963
Massachusetts Institute of Technology, Cambridge: M. S., Structures, 1959
Swiss Federal Institute of Technology, Zurich, Switzerland: B.S., Civil Engineering, 1956

REGISTRATION

Registered Civil Engineer: California
Registered Professional Engineer: Massachusetts

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, San Francisco, California, Principal, 1974-date; Associate and Project Engineer, 1967-1974
Massachusetts Institute of Technology, Department of Civil Engineering, Assistant Professor, Soil Mechanics, 1963-1967
Massachusetts Institute of Technology, Instructor and Research Engineer, 1959-1963
Vevey Iron Works, Switzerland, Design Engineer, 1957

REPRESENTATIVE EXPERIENCE

Dr. Luscher's professional activities over the last 20 years have covered a broad range of applied geotechnical projects with ever increasing responsibility. At present, he is in charge of a Projects Group which conducts or manages large, often interdisciplinary projects for major industrial and governmental clients. He has recently been responsible for a site evaluation for an LNG plant, a static foundation evaluation for a nuclear power plant, offshore site evaluations, and several applied research projects on field instrumentation. He is also responsible for the extensive WCC soil and rock mechanics laboratory in Oakland, California.

Since mid-1977, Dr. Luscher has managed several studies for the proposed chilled gas pipeline across Alaska. The work has related to trench blasting tests and a review of the existing data base for the project.

From 1970 to 1976, Dr. Luscher was involved nearly full-time in the Trans-Alaska oil pipeline project, leading a group of Woodward-Clyde Consultants' personnel engaged in evaluating geotechnical aspects of the pipeline system. The work included the following major areas:

1. *Review of the pipeline support system, including development and application of criteria to evaluate the need for above-ground construction. This task included an extensive laboratory testing program of permafrost samples and evaluations of soil stability.*

2. *Development of design criteria and mile-by-mile design information for vertical support members of the above-ground pipeline. This task included field tests on prototype support members.*

3. *Geotechnical field engineering during construction, and development of guidelines for design changes in response to field conditions different from those assumed in the design.*

4. *Preparation of surveillance and monitoring manual, and of parts of maintenance and repair manual, for use during pipeline operation.*

Before 1970 Dr. Luscher acquired extensive experience in many phases of geotechnical engineering including foundations, earth retaining structures, land development, earth structures and underground conduits. He also worked on several projects involving nuclear power stations and the effects of earthquakes and other dynamic loads.

Dr. Luscher has also conducted projects involving foundation instrumentation, performance monitoring, and correlation between observed and predicted foundation performance. He has done research on the interaction of soil and underground structures and the failure conditions of foundations under static and dynamic loads.

AFFILIATIONS

American Society of Civil Engineers
International Society of Soil Mechanics and Foundation Engineering
Structural Engineers Association of Northern California

PUBLICATIONS

The following is a partial list of publications. A full list will be provided on request.

"Geotechnical aspects of Trans-Alaska Pipeline", with W. T. Black and K. Nair, Proceedings ASCE, Vol. 101, No. TE4, Nov. 1975.

"Thaw consolidation of Alaskan silts and granular soils", with S. S. Afifi, . .mafrost: North American Contribution to 2nd International Conference, 1973.

"Design, construction and performance of cellular cofferdams", with Y. Lacroix and M. I. Esrig, State-of-the-Art, ASCE Specialty Conference on Lateral Stresses and Design of Earth-Retaining Structures, June 1970.

Woodward-Clyde Consultants

Rupert G. Tart, Jr.

geotechnical engineering
project management
remote sensing
rock mechanics/blasting

EDUCATION

University of Virginia: B.C.E., Civil Engineering, 1965
West Virginia University: M.S., Civil Engineering, 1966

REGISTRATION

Registered Civil Engineer: Alaska, California, Colorado, New Mexico

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, Los Angeles/Orange, California; Albuquerque, New Mexico; Anchorage, Alaska; Project Engineer and Geotechnical Manager, 1972-date

San Bernardino Valley College, San Bernardino, California, Part-time Instructor, 1972-1974

Pioneer Testing Laboratory, Redlands, California, Vice President and Chief Soils Engineer, 1971-1972

U.S. Air Force Space and Missile System Organization, Norton AFB, California, Project Officer (Captain), 1967-1971

Tri-State College, Angola, Indiana, Instructor in Civil Engineering, 1966-1976

REPRESENTATIVE EXPERIENCE

Mr. Tart has over 13 years' experience in geotechnical engineering and the management of geotechnical engineering aspects of major projects. He is currently geotechnical manager of the Anchorage office of Woodward-Clyde Consultants. His most recent experience has been in geotechnical engineering in an Arctic environment. He was the project manager for a program for Northwest Alaskan Pipeline Company to determine the feasibility of blasting to excavate rock and permafrost adjacent to an existing pipeline. He has provided similar services in rock b[illegible]ting consultation to Northwest in Utah and Wyoming.

In his original Alaskan assignment, he managed the development of several large computer systems used to design vertical support members (piles) for the trans-Alaska pipeline. In addition, he has participated in the preparation of geotechnical manuals related to the operation of the pipeline. Mr. Tart has also made major contributions to other projects in Alaska including an OCS Terminal Impact Study for Kodiak and a study in which the ground motions caused by blasting frozen soil deposits were evaluated.

Prior to the Alaska assignment, Mr. Tart was responsible for the management of the geotechnical aspects of the Very Large Array (VLA) Radio Telescope project near Soccorro, New Mexico and was geotechnical manager of the WCC Albuquerque office. His experience has also encompassed other projects including missile silos, roadways, residential subdivisions, high explosive test facilities, manufacturing plants, airfield pavement design, earth dam design, radio telescope foundation design, major pipelines, and other structures.

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In addition, Mr. Tart has experience in working with expansive soils, collapsing soils, permafrost, groundwater, explosives, and remote sensing. He has also been an instructor in Civil Engineering.

AFFILIATIONS

American Society of Civil Engineers
Society of American Military Engineers
Earthquake Engineering Research Institute
International Society of Soil Mechanics and Foundation Engineering
National Society of Professional Engineers
Society of Petroleum Engineers

PUBLICATIONS

"Foundation Design for a Very Large Array Radio Telescope", with G. R. Mehdiratta, A. Mahmood, and R. G. Vaughan, presented at the 4th Southeast Asian Conference on Soil Engineering, Kuala Lumpur, Malaysia, April, 1975.

"Computer System Used to Design Vertical Support Members for Trans-Alaskan Pipeline", with O. S. Ghuman, presented at ASCE Specialty Conference, Pipelines in Adverse Environments, New Orleans, January 1979.

"Pipeline Trenching with Explosives in Frozen Ground", with L. Oriard, presented at ASCE Specialty Conference, Pipelines in Adverse Environments, New Orleans, January 1979.

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Woodward-Clyde Consultants

George E. Brogan

engineering geology
seismic geology
structural geology
geomorphology

EDUCATION

San Diego State College: M.S., Geology, 1969
San Diego State College: B.A., Geology, 1966

REGISTRATION

Registered Geologist: California
Certified Engineering Geologist: California

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, Los Angeles/Orange, California, Associate, 1978-date; Deputy Director of Geology, 1976-date; Oakland, California, Staff Geologist to Senior Project Engineering Geologist, 1971-1975
Woodward-Lundgren and Associates, Oakland, California, Consultant in Geology, 1969-1971
University of Nevada, Reno, Department of Geology-Geography, Teaching Fellow, 1968-1971
Humble Oil and Refining Co., Kingsville, Texas, Production Geologist, 1967
San Diego State College, Department of Geology, Teaching Assistant, 1966-1968
U.S. Navy Electronics Laboratory, San Diego, California, Data Analyst with San Deigo State College Foundation, 1964-1968

REPRESENTATIVE EXPERIENCE

Mr. Brogan has practiced engineering geology since 1966, and has world-wide experience in engineering geology and seismic geology on projects including nuclear and conventional power plants, dams, tunnels, pipelines, airports, high-rise buildings, offshore drilling platforms, and liquefied natural gas terminals. In connection with these numerous investigations, he has completed complex projects in diverse geographic and climatic environments. He was in charge of the evaluation of active faults for the Trans-Alaska Pipeline System, the evaluation of the Boconó fault in Venezuela for the Yacumbú tunnel, the mapping and evaluation of the Wasatch fault in Utah, the evaluation of seismic activity and faults for several power plants in Italy, studies for nuclear power plant siting in Iran, evaluations of dams and dam sites in North and South America, and mapping active faults for land-use planning in Managua, Nicaragua. He has completed studies of seismic and geologic hazards in offshore areas of California, Alaska, and the Caribbean.

PUBLICATIONS

Mr. Brogan has authored or co-authored more than 30 professional publications that have appeared in numerous scientific and engineering journals and proceedings of conferences and symposia. These publications include studies of the effects of recent earthquakes, case histories of studies of faulting and seismicity in many localities, and philosophical discussions regarding mitigation of geological hazards. A complete list of Mr. Brogan's publications will be provided upon request.

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Norma E. Biggar

geology

EDUCATION

University of Alaska, Fairbanks: M.S., Geology, 1974
Antioch College, Yellow Springs, Ohio: B.A., Geology, 1970

REGISTRATION

Registered Geologist: California
Certified Engineering Geologist: California

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, San Francisco, California, Staff Geologist to Project Geologist, 1973-date
Geophysical Institute, University of Alaska, Research Assistant, 1971-1973
Wright State University, Teaching Assistant, Department of Geology, 1971
Dr. Ronald G. Schmidt, Consulting Geologist, Yellow Springs, Ohio, Drafts-person, 1971

REPRESENTATIVE EXPERIENCE

Ms. Biggar has served as the project geologist for the active fault identification study for the proposed Alcan gas pipeline in Alaska; and for the geological and seismological investigations of the New Melones Dam site in California.

She served as technical editor for the Woodward-Clyde Consultants' book, "Age Dating of Geologic Materials", in addition to researching and compiling many of the age-dating discussions presented in the book, and is presently preparing a manuscript of the book for publication. Since joining Woodward-Clyde, she has also been involved in regional geologic studies for the siting of a proposed LNG plant at Yakutat, Alaska, nuclear reactors in the Persian Gulf of Iran, Italy, and the Central Valley of California, and the detection of active faults for the Trans-Alaska pipeline project.

An overall geologic study of the Chena Hot Springs area near Fairbanks, Alaska was the topic of Ms. Biggar's Master's Thesis. This investigation included a 35-square mile mapping project of the granitic and metamorphic units in the vicinity of the thermal springs, and geochemical, geophysical and ground temperature studies in the thermal area.

AFFILIATIONS

Geological Society of America
Association of Women Geoscientists
Association of Engineering Geologists

NEB 6-78

Norma E. Biggar

PUBLICATIONS

"Alaska's geothermal resource potential", with R. B. Forbes, The Northern Engineer, V. 5, No. 1, 197 .

"Identification of distinguishing characteristics of late Quaternary faults in the Western Sierran foothills, California", with R. F. Harpster and C. L. Taylor, Abstracts, Earthquake Notes, V. 49, no. 1, pp. 88-89, 1978.

"Evaluation of Quaternary faulting in colluvium and buried paleosols, Western Sierran Foothills, California", with W. D. Page, F. H. Swan III, R. Harpster and L. S. Cluff, Abstracts with Programs, Cordilleran Section, Geological Society of America, V. 10, no. 3, p. 141, 1978.

NEB 6-78

William U. Savage

seismology
geophysics
seismic geology

EDUCATION

University of Nevada, Reno: Ph.D., Seismology, 1976
University of Nevada, Reno: M.S., Seismology, 1971
University of Washington: National Science Foundation Graduate Fellow, Geophysics, 1966-1968
University of Oregon: B.S., Physics, 1966

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, San Francisco, California, Senior Project Seismologist, 1974-date
United States Geological Survey, Menlo Park, California, Research Associate, 1973-1974
University of Nevada, Reno, Seismological Research Assistant, 1969-1973

REPRESENTATIVE EXPERIENCE

Dr. Savage has applied his seismological research experience and training to a large number of projects at Woodward-Clyde Consultants. He has conducted historical seismicity evaluations, seismotectonic interpretations, and seismic safety analyses for high-rise buildings, thermal and nuclear power plant sites, offshore oil developments, and other critical engineering projects, both in the United States and overseas. Dr. Savage has recently completed several major investigations of microearthquake occurrence as related to the development of seismic design criteria for major projects. These projects, in the United States, the Middle East, and Latin America, involved the design and installation of both portable and permanent telemetered arrays of field microearthquake recorders, the analysis of the resulting data, and the interpretation of the results leading to seismic safety and design information. These studies have been significant in understanding earthquake hazards in complex geologic environments. Dr. Savage is leading the Woodward-Clyde Consultants program in developing additional capabilities in microearthquake instrumentation and applications.

During the past several years, Dr. Savage has participated as a key member representing the fields of seismology on several interdisciplinary project teams. These projects have involved siting studies and safety analyses for the major dams of Auburn, California, the Coca River, Ecuador, and the Chulac and Xalala projects, Guatemala, and for the nuclear power plants at Hanford, Washington, Humboldt Bay, California, and San Onofre, California, and proposed plants at Stanislaus, California, and in Southern Iran. Dr. Savage has directed field studies and data analyses for seismological aspects of the projects and has worked with other technical experts in the earth sciences and engineering to synthesize and integrate the results of the investigations performed and to mutually develop and apply the methodologies leading to specific engineering results.

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Dr. Savage has recently completed a study of the seismicity of the Alaskan Interior for the proposed Alcan gas pipeline. In this study, detailed analyses of the microearthquake data along and east of the Denali fault were carried out to assess the location, level of activity, and sense of movement of potentially active faults.

While with the U.S. Geological Survey's National Center for Earthquake Research as a Postdoctoral Research Fellow, Dr. Savage participated in studies of historical seismicity, microearthquake seismicity, and seismic velocities pertinent to earthquake prediction. At the University of Nevada, Dr. Savage helped supervise the installation of a statewide telemetered seismic network and studied the statistical occurrence features of earthquake activity.

AFFILIATIONS

American Association for the Advancement of Science
American Geophysical Union
Seismological Society of America
Geological Society of America
Earthquake Engineering Research Institute

PUBLICATIONS

Dr. Savage has authored numerous reports and portions of reports ranging from brief summaries of site-related observations to lengthy presentations of the technical results of major studies and to regulatory agency documentation such as Preliminary Safety Analysis Reports for the U.S. Nuclear Regulatory Commission. In addition, much of his work has received peer review within the academic and professional community through presentations at scientific meetings and the publication of technical articles in professional journals. A complete list of publications is available upon request. Dr. Savage has also presented technical seminars and public lectures both locally and abroad on topics related to earthquake hazards, current seismological research, and engineering seismology.

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