UNIVERSITY OF UND NORTH DAKOTA

GL00942

DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING
BOX 8068, UNIVERSITY STATION
GRAND FORKS, NORTH DAKOTA 58202
(701) 777-2811

Rec July 20, 1992 HPR

July 15, 1992

University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108
Attn: Howard P. Ross

Dear Howard:

Enclosed are three (3) copies of a map titled, "Geothermal Resources Map of South Dakota." This is a late deliverable initiated under DOE Grant DE-FG07-85ID2606 and completed under DOE Grant DE-FG07-88ID812736.

This map was originally to be produced by the North Dakota Geological Survey as part of the initial grant. Unfortunately, several things occurred during the period of the initial grant that precluded timely production of the map. The North Dakota Geological Survey was reorganized. The offices were moved from the University of North Dakota in Grand Forks to Bismarck, and the drafting and mapmaking facilities were discontinued.

When that occurred, we reached an agreement with DOE to produce the map in a black and white version. However, we were still faced with a lack of mapmaking facilities. Consequently, it has been a long arduous task for us to finish the map.

We have a mylar original and a number of copies on hand. If the Department of Energy so desires, we can provide a mylar original.

Sincerely,

W.D. Gosnold

Dr. William D. Gosnold

Enclosures 3

Final Report

Geothermal Resource Assessment South Dakota

Prepared by:

William D. Gosnold, Jr.
Department of Geology and Geological Engineering
Mining and Mineral Resources Research Institute
University of North Dakota
Grand Forks, North Dakota 58202

Prepared for:

The United States Department of Energy
under
DOE Contract No. DE FG07-85ID12606

Bulletin No. 87-07-MMRRI-01

July, 1987

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

January 17, 1992

Dr. Will Gosnold
Department of Geology and Geological Engineering
P. O. Box 8068, University Station
Grand Forks, North Dakota 58202

Dear Will:

Congratulations! The long awaited Geothermal Resource Map of South Dakota is nearly completed, and in general it looks pretty good. It is hard to put as much information on in black and white as the other state resource maps have in multicolor. I have a few questions and comments which are attached and written on the copy of the map which you sent me.

I think it is desirable to make the map look similar to the other state resource maps, even though the scale is different and there is no color. A heavy border around the map, and map titles on the top and in the upper right hand corner would help to do this and would be useful for quick recognition and identification. You may also wish to add a thin inner border line. Other than appearance, the major concern is accuracy. There is problem with the scale of the map and the scale of the scale bar, and these do not agree. There needs to be some explanation of the contour values, and perhaps a listing of the contours, since there is no uniform contour interval. There seems to be few, if any, control points for the eastern 30% of the state.

Some additional problems are shown on the map, and attached. Most of this should just require a little drafting time, since the base and most of the geothermal information has been completed. Please call me if you wish to discuss any of my comments or think these suggestions would involve too much work to correct for the final map. You are almost done, and I know you want to have a good final product.

Sincerely,

Howard P. Ross

Howard P. Ross
Section Head/Applied Geophysics

January 17, 1992

Dr. Will Gosnold
Department of Geology and Geological Engineering
P. O. Box 8068, University Station
Grand Forks, North Dakota 58202

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Some additional problems are shown on the map, and attached. Most of this should just require a little drafting time, since the base and most of the geothermal information has been completed. Please call me if you wish to discuss any of my comments or think these suggestions would involve too much work to correct for the final map. You are almost done, and I know you want to have a good final product.

Sincerely,

Howard P. Ross
Section Head/Applied Geophysics

REVIEW COMMENTS

GEOTHERMAL RESOURCES OF SOUTH DAKOTA MAP

1 Map would look more like a finished product with heavy outer border, and perhaps a thin inner boder.

2 Map should have a bold title with date at the top, and in the upper right hand corner.

3 There is a problem with the map scale. At 1:1,000,000 the townships are about 7.8 to 8 miles on a side.

4 The map bar scale is not 1:1,000,000 or even the same as the map scale - it is about 40% too large.

5 The line weight and highway symbol size is different in the explanation than it is in the map.

6 The key for population and geothermal application is confusing.

7 The positions of several latitude and longitude ticks appear to be incorrect.

8 Identify the units for heat flow values and contours, and list the contour values since there is no uniform contour interval.

9 Fraction and exponent values are too small to read in Metric Conversions - they may not reproduce well.

10 A useful addition to the map would be a short paragraph describing the stratabound geothermal resources of South Dakota, and giving the reference to your final reports. If this seems like too much drafting, it could be done on a word processor, reduced, and pasted on a paper copy of the map for easy reproduction by large frame copier. A good location would be beneath the temperature contour map of the Dakota.

11 No specific heat flow values define the 130 contours near Gregory. Should contours be added to match the heat flow values near Phillip and Martin?

12 It is hard to follow the contours across the map because of similar line weights. I realize it may be difficult to change the line weights, but perhaps some more contour values could be added.

13 Map could be trimmed to the size I have indicated.

U N I V E R S I T Y O F UND N O R T H D A K O T A

DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING
BOX 8068, UNIVERSITY STATION
GRAND FORKS, NORTH DAKOTA 58202
(701) 777-2811

Opened @ UURI
1/16/92 HPR

January 10, 1992

Howard Ross
University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Dear Howard:

Enclosed is a copy of the South Dakota Geothermal Resource Map for your review. It was delayed for one week due to a heavy work load in the graphics department.

As you know, we were forced to make the map from scratch because no base map existed for the state at the scale of this map. We have produced a mylar original which may be altered and copied to accommodate any changes or suggestions. I am looking forward to finally completing DE-FG07-85ID12606.

I look forward to hearing from you.

Sincerely,

Will Gosnold

Will Gosnold

Energy & Environmental Research Center

Fuels & Process Chemistry Research Institute
ND Mining & Mineral Resources Research Institute
Combustion & Environmental System Research Institute

Box 8213, University Station / Grand Forks, North Dakota 58202-8213 / Phone: (701) 777-5000 / Fax: 777-5181

September 27, 1991

Rec 9/30/91

1 copy sent to DOE earlier, about 9/15/91.
HPR

Mr. Howard Ross
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Dear Mr. Ross:

RE: GRANT NO. DE-FG07-88ID12736

Enclosed please find a copy of Volume 2, "Engineering Report," of the final report entitled "Study of the Geothermal Production Potential in the Williston Basin, North Dakota."

If you have any questions or comments, please feel free to contact me at (701) 777-2811.

Sincerely,

W.D. Gosnold

William D. Gosnold
Professor, Geology and Geological Engineering

WDG/tkk

Enclosure

UNIVERSITY OF UTAH RESEARCH INSTITUTE
UURI
EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

September 11, 1991

Dr. William D. Gosnold
Energy & Environmental Research Center
Box 8213, University Station
Grand Forks, North Dakota 58202-8213

Dear Wil:

You have asked me to review the deliverables due to DOE/ID from your geothermal research grants so that we all are clear on what needs to be done to complete DOE requirements.

Please understand that although I serve as the technical project monitor for the DOE State Cooperative Program, UURI is itself a DOE contractor and cannot make statements representing judgments of the Department of Energy.

Grant DE-FG07-85ID12606 originally established a Project Period of August 9, 1985 to August 9, 1986. The final report was submitted to DOE on August 24, 1987, after DOE granted several no cost time extensions (NCTE) for the grant. DOE may have erred in closing out the grant without receiving the completed Geothermal Resource Map of South Dakota, which was to accompany the report and was itself a major deliverable. In trying to simplify the map requirement I advised DOE to accept a black-and-white version, rather than a colored map similar to the other western states maps. DOE has agreed to this, but still has not received the map some five years after the original grant termination date. I understand that you have been constantly updating the database, especially as a result of the work of your 1988 grant. Delivery of the map will complete the deliverable requirements of the 1985 grant.

Grant DE-FG07-88ID12736 established a Project Period of April 1, 1988 to March 31, 1990. DOE awarded NCTEs at your request, extending the termination date to September 30 and December 31, 1990, and then again to March 31, 1991. I believe the DOE/ID contracts people then issued a final deadline of June 10 with some kind of warning. The first of two final reports was submitted to DOE on August 23, 1991. I believe I returned my draft copy of the Min Chu report, with comments, on December 12, 1990. This report is the only remaining deliverable under this grant, and should be submitted as soon as possible.

I should call attention to task 4.9 of Grant DE-FG07-88ID12736 which reads "Disseminate the results of this research at state and national levels through meetings with appropriate state agencies and presentations at professional meetings". I know that your results have been well distributed on the national professional level, but do not know about the dissemination of results on the statewide or regional level. I do appreciate the level-of-detail of temperature, productivity, and depth-of-resource information available to prospective users in your final report. I trust that you will announce the availability of this information so that potential users in North and South Dakota will benefit from your studies.

Wil, I regret that DOE/ID has had to call attention to these late deliveries to administrative levels at the university. DOE has realized that they must wind up old studies and old business in order to reduce government costs and to expedite research results to the public. It is hard for DOE or for me to determine how many of your delays are due to poor support at the institute,or to your own work schedule or research problems, but the supervisory responsibility falls on you. A few other state teams with the 1988 grants are also tardy in their final deliverables, and are subject to the same pressures. Perhaps I share some of the blame for not bugging you more than I did.

Marshall Reed and I certainly appreciate the technical quality of your geothermal research and of the final reports which you have submitted or are forthcoming. We also recognize the visibility you have given to the DOE geothermal programs through your many presentations and publications at the GRC, GSA, and AGU. As far as I am concerned, you are the expert on the stratabound geothermal resource of the Great Plains, and as you have shown, this is a tremendous energy resource.

We look forward to receiving the Min Chu report and the South Dakota Geothermal Resource Map in the near future. I would like to review a draft copy of the map, even if it means a few more days before being printed. Please complete a careful proof reading of the Min Chu report, noting my earlier comments and details like the DOE Disclaimer, correct Grant number, and no reference to the DOE Contract Officer on the title page.

These deliverables should square things with DOE/ID. We want to be certain you are available to participate in any future geothermal research and development projects which may be funded by DOE-Geothermal Division. Please call me if you have any more questions.

Best Regards,

Howard

Howard P. Ross
Project Manager,
State Cooperative Program

Energy & Environmental Research Center

Rec 8/28/91 HPR

Fuels & Process Chemistry Research Institute
ND Mining & Mineral Resources Research Institute
Combustion & Environmental System Research Institute

Box 8213, University Station / Grand Forks, North Dakota 58202-8213 / Phone: (701) 777-5000 / Fax: 777-5181

August 23, 1991

Mr. Howard Ross
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Dear Mr. Ross:

RE: COOPERATIVE AGREEMENT NO. DE-FG07-88ID12736

Enclosed please find a copy of Volume 1, "Resource Assessment," of the final report entitled "Stratabound Geothermal Resources in North Dakota and South Dakota." Volume 2, "Engineering Report," is in the editing process and will be sent shortly.

If you have any questions or comments, please feel free to contact me at (701) 777-2811.

Sincerely,

W.D. Gosnold

William D. Gosnold
Professor, Geology and Geological Engineering

WDG/lrf

Enclosure

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law PL 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Energy Research, Development, and Demonstration Act of 1974

1. PROJECT TITLE
Stratabound Geothermal Resources in North Dakota and South Dakota

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
North Dakota Mining and Mineral Resources Inst.
University of North Dakota, P. O. Box 8103
University Station, Grand Forks, ND 58202

4. INSTRUMENT NO. DE-FG07-88ID12736

5. AMENDMENT NO.

6. BUDGET PERIOD FROM: 4/1/88 THRU: 3/31/89

7. PROJECT PERIOD FROM: 4/1/88 THRU: 3/31/90

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
William D. Gosnold (701) 777-2631

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Alice Brekke (701) 777-5160

10. TYPE OF AWARD
☒ NEW ☐ CONTINUATION ☐ RENEWAL
☐ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Kenneth J. Taylor (208) 526-9063
U.S. DOE, Idaho Operations Office
785 DOE Place, Idaho Falls, Idaho 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Trudy A. Thorne (208) 526-9519
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, Idaho 82402

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☒ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
89X0224.91	AM1510000	410	

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ 194,814
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-
(4) DOE Share of Total Approved Budget	$ 194,814
(5) Recipient Share of Total Approved Budget	$ 44,195
(6) Total Approved Budget	$ 239,009

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 194,814
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 194,814

17. TOTAL ESTIMATED COST OF PROJECT $ 239,009

(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ________ *(Date)* ________

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☒ B (Grants) or ☐ C (Cooperative Agreements).

d. Application/proposal dated June 18, 1987, ☐ as submitted ☒ with changes as negotiated

19. REMARKS

This Grant consists of this NFAA (DOE Form 4600.1), Part I - Budget Plan; Part II - Special Conditions; Part III - General Conditions; Part IV - Statement of Work; Part V - Reporting Requirements. DOE Financial Assistance Rules (10 CFR Part 600), OMB Circular A-110 and OMB Circular A-21 are hereby incorporated by reference.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Alex Kotch 03-31-88
(Signature of Authorized Recipient Official) *(Date)*

Alex Kotch, Director-Office of Research and Program Development
(Name)

(Title)

21. AWARDED BY

J P Anderson 3/30/88
(Signature) *(Date)*

J. P. Anderson, Contracting Officer
(Name)

Chief, R&D Contracts Branch
(Title)

Grant No. DE-FG07-88ID12736
Part I - Budget Plan

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA 459C (10 80) — FORM APPROVED OMB No. 1900-0127

1. Program/Project Identification No. DE-FG07-88ID12736	2. Program/Project Title Stratabound Geothermal Resources in North & South Dakota	
3. Name and Address North Dakota Mining and Mineral Resources Research Insti. Box 8103 University Station Grand Forks, ND 58202	4. Program/Project Start Date April 1, 1988	5. Completion Date March 31, 1990

SECTION A - BUDGET SUMMARY

Grant Program, Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. 12693	81.087	$	$	$	$	$
2. First Year				118,887	21,666	140,553
3. Second Year				75,927	22,529	98,456
4.						
5. TOTALS		$	$	$	$	$

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	Grant Program, Function or Activity: DOE Cost Share		N. Dakota Cost Share		Total (5)
	(1) First Year	(2) Second Year	(3) First Year	(4) Second Yr.	
a. Personnel	$ 28,803	$ 29,917	$ 7,997	$ 8,313	$ 75,030
b. Fringe Benefits	6,913	7,180	1,919	1,995	18,007
c. Travel	7,606	7,606			15,212
d. Equipment					
e. Supplies	1,550	1,550			3,100
f. Contractual	40,000				40,000
g. Construction		N. Dak.	– 6,066	6,309	12,375
		S. Dak.	– 5,684	5,912	11,596
h. Other Research Support 69% of Direct Labor	19,874	20,643			40,517
i. Total Direct Charges	104,746	66,896	21,666	22,529	215,837
j. Indirect Charges 13.5%	14,141	9,031			23,172
k. TOTALS	$ 118,887	$ 75,927	$ 21,666	$ 22,529	$ 239,009
7. Program Income	$	$	$	$	$

NOTE: This Grant is for a two-year period at a total estimated DOE cost of $194,814 and total estimated Grantee cost of $44,195 for a total of $239,009.

This will be funded as follows:

First Year:	DOE -	$118,887	Grantee -	$21,666
Second Year:	DOE -	75,927	Grantee -	22,529
		$194,814		$44,195

Special Terms and Conditions for Research Grants

The requirements of this attachment take precedence over all other requirements of this grant found in regulations, the general terms and conditions, DOE orders, etc. except requirements of statutory law. Any apparent contradiction of statutory law stated herein should be presumed to be in error until the Grantee has sought and received clarification from the Contracting Officer, whose signature appears on the face page of this award.

1. Payments

   a. The Grantee may request advance payment of cost to be incurred. Such requests should not exceed the expected outlays by the Grantee in the succeeding 30-day period.

   b. Payments to the Grantee shall equal the Federal share of actual allowable costs of performance of this grant, provided however, and notwithstanding any other provision of this grant, that the Government's monetary liability under this grant shall not exceed the Government share of the total approved budget or an amount equal to the Federal share of actual allowable costs, whichever is less. The Grantee shall be obligated to perform under this grant throughout the agreed-upon period of performance, and to bear all costs which DOE has not agreed to pay. However, the Grantee shall have the right to cease to perform when or after the Federal share of actual allowable costs equals or exceeds the Government share of the total approved budget and if prior written notice to that effect has been provided to DOE.

   c. The Government obligations may be increased unilaterally by DOE by written notice to the Grantee and may be increased or decreased by written agreement of the parties.

   d. Upon termination or expiration of the total period of performance, the Grantee shall promptly refund to DOE (or make such disposition as DOE may in writing direct) any sums paid by DOE to the Grantee under this grant in excess of the cumulative Government allowable cost incurred in performance under the grant.

   e. Method of Payment - Payments due for amounts properly invoiced in accordance with the terms and conditions specified elsewhere in the grant shall be made either by Treasury check(s) payable to the Grantee or designee or by electronic funds transfer(s) to a financial institution designated by the Grantee for that purpose. The method of payment shall be determined by the Government at the time of payment in accordance with applicable Treasury Department requirements.

After award but no later than fourteen (14) days before an invoice or bill is submitted for payment, the Grantee shall designate a financial institution for the receipt of electronic funds transfer payments hereunder; and provide the appropriate Government representative (contracting officer or finance official as determined by the Government) with the name of the designated financial institution, financial institution's or correspondent financial institution's 9-digit American Bankers Association identifying number, telegraphic abbreviation of such financial institution, and account number at the designated financial institution to be credited with funds.

In the event the Grantee during the performance of this grant elects to designate a different financial institution for the receipt of any payment made using electronic funds transfer procedures, notification of such change and the information as specified in paragraph (b) above must be received by the appropriate Government representative thirty (30) days prior to the date such change is to become effective.

The document furnishing the information required above must be dated and contain the signature, title, and telephone number of the Grantee official authorized to provide it, as well as the Grantee's name and grant number.

Grantee failure to properly designate a financial institution or to provide appropriate payee bank account information may delay payments of amounts otherwise properly due.

f. Cost-Share Arrangement - The cost-share will be in accordance with Part I - Budget Plan and shall be paid as follows. All labor and fringe benefits occurring during the academic year (August 15 - May 15) shall be paid by North Dakota Mining and Mineral Resources. All labor and fringe benefits occurring during the non-academic year (May 16 - August 14) shall be paid by DOE. South Dakota Geological Survey and North Dakota Geological Survey costs shall be incurred and paid by them as part of North Dakota Mining and Mineral Resources' cost-share. Indirect costs associated with North Dakota Mining and Mineral Resources' cost-share will not be billed to DOE nor considered an allowable cost for this grant.

g. Applicable Credits - The Grantee agrees that any refunds, rebates, credits, or other amounts (including any interest thereon) accruing to or received by the Grantee or any assignee under this grant shall be paid by the Grantee to the Government, to the extent that they are properly allocable to costs for which the Grantee has been reimbursed by the Government under this grant. Reasonable expenses incurred by the Grantee for the purpose of securing such refund, rebates, credits, or other amounts shall be allowable costs hereunder when approved by the Contracting Officer.

h. Audit Adjustments - The Contracting Officer may have invoices or vouchers and statements of cost submitted under this grant audited at any time prior to the end of the required retention period for the grant records. Each payment made shall be subject to reduction for amounts included in the related invoice or voucher which are found by the Contracting Officer, on the basis of audit, not to constitute allowable cost. If a final audit of costs has not been performed prior to closeout of the grant, DOE or its successor agency, shall have the right to recover an appropriate amount after fully considering the recommendations on disallowed costs resulting from the final audit when conducted.

i. Cognizant Office - Invoices should be sent to the individual designated in Block 12. of the Notice of Financial Assistance Award Form (NFAA). In addition to the initial supply of forms made available with this award, appropriate payment forms and instructions will be provided by this office upon request.

2. Budget Flexibility and Limitation of DOE Liability

a. Under the terms of this award, grantee may obligate up to 110% of the amount awarded by DOE for a budget period, during that period, without prior authorization by DOE. Obligations in excess of 110% of the amount awarded by DOE require prior DOE authorization. (A prior approval made in accordance with the provisions of paragraph b. of this clause would constitute such prior approval.) Such authorized grantee obligations in excess of the amount awarded by DOE for a budget period shall be funded from unobligated funds remaining from the prior budget period to the extent they are available; or such obligations may be incurred at grantee's own risk, subject to the following conditions:

(1) If grantee receives a continuation or renewal award, the amount obligated in excess of 100% may be charged against the subsequent continuation or renewal award to the extent not funded from any unobligated balance from an earlier budget period.

(2) Even if prior authorization required by this paragraph has been obtained, grantee shall not be entitled to reimbursement, or have any claim against DOE, for any amount obligated by grantee in excess of the total funds obligated by DOE, if a continuation or renewal award is not made.

b. When the funds remaining unobligated by the grantee in any given budget period are 10% or less of the amount awarded by DOE for the subsequent budget period, grantee may use the unobligated funds during the subsequent budget period to pay for costs (1) budgeted for in either budget period and (2) subject to any applicable prior approval requirements. If funds remaining unobligated by the grantee at the end of a budget period exceed 10% of the amount awarded for the subsequent budget period, use of the amount in excess of 10% must receive the prior approval of the Contracting Office.

c. Nothing in paragraphs a. or b. of this article shall in any way require DOE to increase the total obligated for the project period or to make any additional supplemental, continuation, renewal, or other award for the same or any other purpose.

3. Reporting Program Technical Performance

a. Copies. Copies of reports and all other related data and information generated under this grant shall be submitted in accordance with the attached Federal Assistance Reporting Checklist (DOE Form EIA-459A).

b. Publication of Results. The Grantee may publish the results of its work. However, publications and reports prepared under this grant shall contain the following acknowledgment statement, "This (material) was prepared with the support of the U.S. Department of Energy (DOE) Grant No. DE-FG07-88ID12736. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE."

c. Reporting Requirements. The Federal assistance recipient shall prepare and submit (postage prepaid) the plans and reports indicated on the Federal Assistance Reporting Distribution List. Preparation of the specified plans and reports shall be in accordance with DOE Order 1332.2. The level of detail the recipient provides in the plans and reports shall be commensurate with the scope and complexity of the task and shall be as delineated in Block 4 - Reporting Requirements and Block 5 - Special Instructions.

All reports delivered to DOE shall be the sole property of the DOE. The Grantee shall not claim that any report contains any trade secrets or commercial or financial information deemed by the Grantee to be privileged or confidential, or that the Grantee has any proprietary interest in any report.

4. Designated Key Personnel

The following individual is designated key personnel in accordance with General Condition No. 14:

William D. Gosnold

5. Project Completion Date

The project completion date identified in Block 7. of the Notice of Financial Assistance Award includes an additional 90 days for completion of the final report. All R&D effort must be completed 90 days prior to the project completion date. Only costs associated with preparation of the final report will be allowed during the 90 days prior to the project completion date.

6. Technical Data

Except for technical data contained in pages N/A of the recipient's application, dated N/A, which are asserted by the Grantee as being proprietary data, it is agreed that as a condition of this award, and notwithstanding the provisions of any notice appearing on the application, the Government shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever the technical data not identified in the above blanks contained in the application upon which this award is based.

7. Prior Approval

The following actions or costs specified in the application require prior approval of DOE and are specifically disapproved in accordance with General Condition No. 3:

None

8. General Procurement Prior Approval

Article 17 of the General Terms and Conditions for Research Grants is hereby revoked. Grantee must receive prior approval from DOE before entering into any sole source contract or a contract where only one bid or proposal is received, when the value of the contract in the aggregate is expected to exceed $25,000.

9. Patent Clauses

The following patent clauses and technical data requirements are applicable to this grant award:

600.118(b)(1) "Patent Rights (Small Business Firm or Nonprofit Organization)"

600.118(b)(3) "Rights in Technical Data (Short Form)"

600.118(b)(5) "Authorization and Consent"

600.118(b)(6) "Notice and Assistance"

600.118(c) "Reporting of royalties"

10. Title to Equipment

a. Title to the following items of equipment shall vest with the Grantee upon completion of this grant:

None

b. Title to the following items of equipment shall vest with the Government at the end of the grant project period:

None

11. Annual Budget Review

The Budget Plan included in this grant is subject to annual review by DOE. The Grantee shall submit to the DOE Contracting Officer: 1) the status of progress on the research effort; 2) the actual costs to date; 3) the estimated cost to complete the research effort being supported; and 4) any proposed changes to the current budget plan. This information shall be submitted annually in the same level of detail as the original proposal. The annual submission date shall be within 15 days of the day identified as the start date of the budget period in Block 6. of the Notice of Financial Assistance Award. Items 1) and 2) above may be provided as part of the Financial Assistance Management Summary Report (FAMSR) if the annual submission date and the normal FAMSR due date coincide.

wp/Thorne

General Terms and Conditions for Research Grants

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General Terms and Conditions for Research Grants

1. Explanation

These general terms and conditions do not restate all the provisions of applicable statutes and regulations nor do they represent an exhaustive listing of all requirements applicable to this grant. Rather they highlight and are consistent with those requirements which are especially pertinent to research grants in general. They are being emphasized by inclusion here either because they are invoked with high frequency, their violation is a matter of especially serious concern (e.g., use of human subjects), and/or they have been restated in the research context to be more easily understood by the research community.

In addition to these general terms and conditions, the grantee must comply with all governing requirements, including those identified in Block 18 of the Notice of Financial Assistance Award and those included in the Special Terms and Conditions attached to this grant award.

2. Grantee Adherence to Grant Terms and Conditions

The grantee's signature on the application and on the Notice of Financial Assistance Award signifies the grantee's agreement to the terms and conditions of award. Should the grantee believe modification of any of the terms and conditions of this award is necessary, an authorized official of the grantee organization or, in the case of an individual, the grantee, must submit a written request on its own behalf or on behalf of any subgrant recipient or applicant to the Contracting Officer named on the face page of this award.

Following this procedure is very important because many of the terms and conditions of this grant are required by statute and must be enforced by the Department of Energy.

3. Definitions

Principal Investigator

As used herein, the scientist or other programmatic expert named in Block 8 of the Notice of Financial Assistance Award designated by the grantee organization to direct the scientific/technical efforts being supported (also called program director or project director/leader).

Prior Approval

A statement in writing, signed by the DOE Contracting Officer, that a cost may be incurred or an action may be taken. The approval may take the form of a letter or of a revision to the grant. If actions or costs requiring prior approval are specified in the application and are not expressly disapproved by DOE in the attached Special Terms and Conditions, the award of the grant constitutes such prior approval.

4. Authorized Grantee Signatures for Prior Approval Requests

All requests for prior approval must be signed by an individual who is authorized to act for the grantee organization. The signature of the Principal Investigator (unless also a corporate officer or otherwise authorized) is insufficient to obtain action on a prior approval request, although countersignature by the Principal Investigator is not discouraged. Requests for budget revisions shall be made on the same budget format as used in applying for this grant and must be supported by a narrative justification. Other prior approval requests may be made by letter. Prior approval requests should be addressed to the Contracting Officer named on the face page of this award.

5. Allowable Costs/Applicable Cost Principles

In accordance with the applicable cost principles cited below and up to the amount shown on the face page of this award for the total approved budget for the current budget period (line 16.a.(6)), the allowable costs of this grant shall consist of the actual allowable direct costs incident to performance of this project plus the allocable portion of the allowable indirect costs, if any, of the organization less applicable credits.

The allowability of costs for work performed under this grant and any subsequent subaward will be determined in accordance with the Federal cost principles applicable to the grantee or subrecipient in effect on the date of award or, for any subaward, in effect as of the date of that subaward, except as modified by other provisions of this grant or the subaward.

The Federal cost principles applicable to specific types of grantees and subrecipients are:

1. Institutions of Higher Education. OMB Circular A-21, Cost Principles Applicable to Grants, Contracts and Other Agreements with Institutions of Higher Education, is applicable to both public and private colleges and universities.

2. State and local governments and Indian tribal governments. OMB Circular A-87, Cost Principles Applicable to Grants, Contracts and other Agreements With State and Local Governments, is applicable to state, local, and Indian tribal governments (and shall also be used to the extent appropriate for foreign governments).

3. Hospitals. 4S CFR Part 74, Appendix E, Principles for Determining Costs Applicable to Research and Development under Grants and Contracts with Hospitals, applies to nonprofit and for-profit hospitals.

4. Other nonprofit organizations and individuals. OMB Circular A-122, Cost Principles Applicable to Grants, Contracts, and other Agreements with Nonprofit Organizations, applies to nonprofit organizations and individuals except for nonprofits specifically exempted by the terms of the circular or those nonprofits covered by the cost principles cited in items 1.- 3. above.

5. Commercial firms and certain nonprofit organizations. 48 CFR Subpart 31.2, Contracts with Commercial Organizations, as supplemented by 48 CFR Subpart 931.2, applies to those nonprofit organizations not covered by OMB Circular A-122, as specified by the terms of that circular, and to all commercial organizations other than those covered by the cost principles in item 3. above.

6. Payment

Payments under this award will be made by an advance payment method unless DOE determines that the grantee's financial management system does not meet the requirements of 10 CFR 600.109 or the grantee has not maintained, or demonstrated the willingness and ability to maintain, procedures that will minimize the time elapsing between transfer of funds from the U.S. Treasury and their disbursement for grant-related purposes.

The appropriate advance payment method or the reimbursement method and the cognizant finance office are specified in the attached Special Terms and Conditions.

Advances by the grantee to subgrantee and contractor organizations must conform substantially to the same standards of timing and amount that govern advances made by the Federal Government to the grantee. Excess cash advances erroneously withdrawn from the U.S. Treasury shall be promptly refunded to DOE unless the funds will be disbursed within seven calendar days or the amount is less than $10,000 and will be disbursed within 30 calendar days.

Interest earned on advance payments to other than state governments or their subgrantees shall be reported on the Report of Federal Cash Transactions (SF-272) and promptly remitted to the cognizant finance office (unless otherwise specified in the attached Special Terms and Conditions) by check payable to the Department of Energy.

7. Preaward Costs

Costs incurred prior to the beginning date of a new or renewal award are allowable only if they were approved in writing, prior to incurrence, by a DOE Contracting Officer. (Note - this provision does not apply to such bid and proposal costs as may be recovered through an indirect cost rate negotiated in accordance with the applicable Federal cost principles.)

8. Reporting Requirements

Attached to this grant award is EIA 459A, a checklist of the reports required under this grant.

The grantee shall submit a technical progress report (also called a performance report) as part of any application for continuation or renewal of DOE grant support. This report shall be in lieu of a separate annual performance report. Upon completion or termination of the project, the final technical report shall be prepared in accordance with the applicable program rule cited on the face page of this award or, in the absence of such program rule coverage, with the technical reporting format specified in the Uniform Reporting System for Federal Assistance (Grants and Cooperative Agreements) (DOE/MA-001).

The grantee shall submit an annual Financial Status Report (SF-269) within 90 days after the close of the budget period shown on the face page of this award. The grantee shall submit a final Financial Status Report within 90 days after the completion or termination of the project period shown on the face page of this award unless the project period is extended. In the latter case, the report for the last budget period of the existing project period shall be considered an annual report.

Instructions concerning reports to be submitted in conjunction with payment under this award are specified in the attached Special Terms and Conditions.

9. Cost-Sharing

Any cost-sharing as shown on the face page of this award shall defray allowable costs of the project only. Allowability of such costs shall be determined in accordance with the statutes, regulations, applicable cost principles, and other terms and conditions governing this award.

Cost-sharing contributions may be in the form of direct or indirect costs, including cash or in-kind contributions, incurred by the grantee, its subgrantees, or contractors. The cost sharing may be in any allowable budget category or combination of categories. When a direct cost item represents some or all of the non-Federal contribution, any associated indirect costs may not be charged to Federal funds but may be counted as part of the cost-sharing. The treatment of a contributed cost as direct or indirect must be consistent with the classification of similar items charged to DOE funds.

Valuation of in-kind contributions and documentation of cost-sharing shall be in accordance with 10 CFR 600.107.

10. Continuations, Renewals, and Extensions

Grantees are responsible for assuring that properly completed applications for continuation awards are received no later than 4 months prior to the expiration date of the current budget period shown on the Notice of Financial Assistance Award.

If a grantee wishes to apply for a renewal award in order to receive funding beyond the scheduled expiration of the existing project period, a properly completed application must be submitted to DOE no later than four months prior to the scheduled expiration date of the project period as shown on the Notice of Financial Assistance Award.

Grantee requests for extensions (modifications extending an existing project period by 18 months or less in order to complete a project) must be submitted prior to the expiration date of the project period as shown on the face page of this award, and must include a budget for the use of any remaining funds or any additional funds requested. Any request for an extension, which includes a request for additional funds and any request for an extension of more than 90 days, should be submitted to DOE no later than four months prior to the scheduled expiration date of the project period.

11. Maximum DOE Obligation

This grant is subject to the requirement that the maximum DOE obligation to the recipient is the amount shown on the Notice of Financial Assistance Award as the amount of DOE funds obligated. DOE shall not be obligated to make any additional, supplemental, continuation, renewal or other award for the same or any other purpose.

12. Transfers of Funds Between Grants

Transfers of funds between DOE grants, and transfers of funds from a DOE grant to a project (or portion of a project) not supported by that grant require the prior approval of DOE. Transfer of funds into a DOE grant-supported project from a grant awarded by another Federal agency does not require DOE prior approval but may, of course, require the approval of the other Federal agency. Funds so transferred from the grant of another Federal agency may not be used to satisfy any cost-sharing requirement on a DOE grant.

13. Property

Real and Tangible Personal Property

No real property may be acquired under this award.

Title to any equipment (an article of tangible personal property that has a useful life of more than 2 years and an acquisition cost of $500 or more) or supplies acquired by a nonprofit institution of higher education or a nonprofit organization whose primary purpose is the conduct of scientific research shall vest in the grantee and such equipment shall be exempt from accountability except that DOE has the right to transfer ownership of any item of equipment having a unit acquisition cost of $1,000 or more under the conditions specified in 10 CFR 600.117(d)(2). This exemption is derived from Public Law 95-224. The Federal Grant and Cooperative Agreement Act of 1977, as amended.

Title to equipment and supplies acquired by all other grantees shall vest in the grantee. However, such grantees shall be accountable for equipment with a unit acquisition cost of $1,000 or more acquired under this grant as specified in 10 CFR 600.117(d)(2), (3) and (4). For such grantees, supplies need only be accounted for at closeout and then only if they are unused and exceed $1,000 in total aggregate current fair market value. In this case accountability requires that DOE be compensated in an amount computed in accordance with Section 600.117(e) if the supplies are retained for use on non-Federal activities.

All grantees shall follow property management policies and procedures which provide for adequate control of the acquisition and use of assets acquired under the grant.

Intangible Property

Treatment, including reporting, of patent and data rights and copyrights shall be as specified in the Special Terms and Conditions of this grant.

14. Change or Absence of the Principal Investigator or Designated Key Personnel

Since the DOE decision to fund a project is based, to a significant extent, on the qualifications and level of participation of the Principal Investigator, a change of Principal Investigator or of the level of effort of the Principal Investigator is considered a change in the approved project. The approval of DOE must be obtained prior to any change of the Principal Investigator or, in certain cases, other key personnel who have been identified as key personnel in the Special Terms and Conditions of this grant. In addition, any continuous absence of the Principal Investigator in excess of three months or plans for the Principal Investigator to become substantially less involved in the project than was indicated in the approved grant application requires DOE prior approval. Grantee is encouraged to contact DOE immediately upon becoming aware that any of these changes are likely to be proposed, but in any event must do so and receive DOE prior approval before effecting any such change.

15. Changes in Objectives or Scope

Any change in the objectives or scope of a grant-supported project requires the prior approval of DOE. Such changes include changes in the phenomenon or phenomena under study and in the methodology or experiment if they are a specific objective of the research work as stated in the application approved by DOE.

16. Transfer of Substantive Programmatic Effort

None of the substantive effort of this project may be transferred by contract or subgrant to another organization or person without the prior approval of DOE. This provision does not apply to the procurement of equipment, supplies, materials, or general support services which may, however, be subject to other prior approval requirements as found, for example, in the applicable cost principles or procurement standards.

17. General Procurement Prior Approval Requirements

A grantee must receive prior approval from DOE before entering into any sole source contract or a contract where only one bid or proposal is received when the value of the contract in the aggregate is expected to exceed 1) $10,000 and the grantee is a state, local, or Indian tribal government or 2) $5,000 for all other grantees.

18. Equipment and Other Capital Expenditures

Expenditures for equipment and other capital assets having a unit acquisition cost of $500 or more require the prior approval of DOE with one exception. For special purpose equipment, prior approval is required only when the unit acquisition cost is $1,000 or more. (Special purpose equipment means equipment which is used only for research, medical, scientific, or other technical activities.)

19. Travel

Foreign Travel - DOE prior approval is required for each separate foreign trip. Foreign travel must be directly related to the project objectives. Foreign travel is any travel outside Canada and the United States and its territories and possessions or, for grantees located in another country, travel outside that country.

Domestic Travel - Such costs are allowable to the extent provided in the approved budget. In addition, grantees may exceed the approved budget amount for domestic travel by up to 25% or $500 whichever is greater, without DOE prior approval. All other expenditures for domestic travel beyond these limits require prior approval.

20. Consultant Services

Costs of consultant services are allowable subject to satisfaction of the requirements of the applicable cost principles, including the requirement that the consultant not be an employee of the grantee organization. *There is one exception to the requirement that the consultant not be an* employee of the grantee organization which applies to colleges and universities only. For colleges and universities, in unusual cases, and only with the prior approval of DOE, intra-organizational consultation may be permitted where consultation is across departmental lines or involves a separate or remote operation.

21. Paperwork Reduction

This award is subject to the requirements of the Paperwork Reduction Act of 1980 as implemented by the Office of Management and Budget rules, "Controlling Paperwork Burdens on the Public," published at 5 CFR 1320 (48 FR 13666, 3/31/83) if the grantee will collect information from ten or more respondents either:

A. At the specific request of DOE, or

B. If the award requires specific DOE approval of the information collection or the collection procedures.

Any proposed sponsored information collection under item 21 B. above shall be submitted by the grantee to the Contracting Officer named on the face page of this award at least 90 days prior to the intended date of information collection. DOE will seek the requisite approval from the Office of Management and Budget and will promptly notify the grantee of the disposition of the request.

22. Generally Applicable Requirements

In accordance with 10 CFR 600.12, this grant is subject to a number of statutory and other generally applicable requirements. Those requirements most pertinent to research projects are highlighted below:

Animal Welfare

Any grantee performing research on warm-blooded animals shall comply with the Laboratory Animal Welfare Act of 1966 (Public Law 89-544, as amended) and the regulations promulgated thereunder by the Secretary of Agriculture at 9 CFR Chapter 1, Subchapter A, pertaining to the care, handling, and treatment of warm-blooded animals held or used for research, teaching, or other activities supported by Federal awards. The grantee is expected to ensure that the guidelines described in Department of Health and Human Services (DHHS) Publication No. [NIH] 78-23, "Guide for the Care and Use of Laboratory Animals," are followed (Copies are available from the Superintendent of Documents, Government Printing Office, Washington, DC 20024, Stock No. 017-040-00427-3).

Research Involving Recombinant DNA Modecules

Any grantee performing research involving recombinant DNA molecules and/or organisms and viruses containing recombinant DNA molecules agrees by acceptance of this grant to comply with the National Institutes of Health "Guidelines for Research Involving Recombinant DNA Molecules," June 1983 (48 FR 24556) or such later revision of those guidelines as may be published in the Federal Register.

Use of Human Subjects in Research, Development, and Related Activities

Any DOE grantee performing research, development, or related activities involving any use of human subjects must comply with DOE regulations found at 10 CFR Part 74S "Protection of Human Subjects" and any additional Provisions which may be included in the Special Terms and Conditions of this grant. Such provisions are intended to safeguard the rights and welfare of human subjects at risk of possible physical, psychological, or social injury as a consequence of their participation.

23. Nondiscrimination

This grant is subject to the provisions of 10 CFR Part 1040 "Nondiscrimination in Federally Assisted Programs."

24. Public Access to Information

The Freedom of Information Act, as amended, and the DOE implementing regulations (10 CFR Part 1004) require the release by DOE of certain documents and records regarding grants upon written request by any member of the public. The intended use of the information will not be a criterion for release. These requirements apply to information held by DOE, and do not require grantees, their subgrantees, or their contractors to permit public access to their records.

Records maintained by DOE with respect to grants are subject to the provisions of the Privacy Act and the DOE implementing regulations (10 CFR Part 1008) if those records constitute a "system of records" as defined in the Act and the regulations. Generally, records maintained by grantees, their subgrantees, or their contractors are not subject to these requirements.

25. Acknowledgement of Support

Publication of the results of this grant, subject to any applicable restrictions in 10 CFR 600.118 ("Patents, data, and copyrights"), is encouraged. Any article which is published shall include an acknowledgement that the research was supported, in whole or in part, by a DOE grant (including the grant number), but that such support does not constitute an endorsement by DOE of the views expressed in the article.

26. National Security

It is not expected that activities under this grant will generate or otherwise involve classified information (i.e., Restricted Data, Formerly Restricted Data, National Security Information).

However, if in the opinion of the grantee or DOE such involvement becomes expected prior to the closeout of the grant, the grantee or DOE shall notify the other in writing immediately. If the grantee believes any information developed or acquired may be classifiable, the grantee shall not provide the potentially classifiable information to anyone, including the DOE officials with whom the grantee normally communicates, except the Director of Classification, and shall protect such information as if it were classified until notified by DOE that a determination has been made that it does not require such handling. Correspondence which includes the specific information in question shall be sent by registered mail to U.S. Department of Energy, Attn: Director of Classification, DP-32, Washington, DC 20545. If the information is determined to be classified the grantee may wish to discontinue the project, in which case the grantee and DOE shall terminate the grant by mutual agreement. If the grant is to be terminated, all material deemed by DOE to be classified shall be forwarded to DOE, in a manner specified by DOE, for proper disposition. If the grantee and DOE wish to continue the grant, even though classified information is involved, the grantee shall be required to obtain both personnel and facility security clearances through the Office of Safeguards and Security. Costs associated with handling and protecting any such classified information shall be negotiated at the time the determination to proceed is made.

27. Liabilities and Losses

DOE assumes no liability with respect to any damages or loss arising out of any activities undertaken with the financial support of this grant.

28. Contracting Officer's Technical Representative (COTR)

The individual identified in Block 11. of the Notice of Financial Assistance Award as the DOE Project Officer is the Contracting Officer's Technical Representative (COTR). The COTR is responsible for

1) monitoring the research efforts being conducted by the Grantee under the scope of this award; 2) advising the Contracting Officer on technical matters related to administration of the grant, including progress and status of the Grantee's research; and 3) providing technical advice and guidance to the Grantee in order to assist both the research efforts of the Grantee and the Grantee's adherence to the grant terms and conditions.

The COTR does not have the authority to:

Cause an increase or decrease in the total estimated cost of, or the time required for, the research effort being supported;

Cause any change in the express terms and conditions of the grant;

Cause any change in the objectives or scope of the effort being supported;

Act in the capacity of the Contracting Officer by issuing any approval or disapproval required by the terms and conditions of the grant;

Interfere with the Grantee's right to perform under the terms and conditions of the grant.

29. Interest

(a) Notwithstanding any other term or conditions of this grant, all amounts that become payable by the recipient to the Government under this grant shall bear simple interest from the date due until paid unless paid within 30 days of becoming due. The interest rate shall be the interest rate established by the Secretary of Treasury (Secretary) as provided in Section 11 of the Debt Collection Act of 1982 (31 U.S.C. 3717), which is applicable to the period in which the amount becomes due, as provided in paragraph (b) of this provision, and then at the rate applicable for each three-month period as fixed by the Secretary until the amount is paid.

(b) Amounts shall be due at the earliest of the following dates:

(1) The date fixed under this grant.

(2) The date of the first written demand for payment consistent with this grant, including any demand resulting from a termination.

(3) The date the Government transmits to the recipient a proposed agreement to confirm completed negotiations establishing the amount of debt.

(c) The interest charge made under this provision may be reduced in accordance with the procedures prescribed in 4 CFR 102.13 or in accordance with agency regulations in effect on the date of original award of this grant.

wp/Thorne

STATEMENT OF WORK

1.0 INTRODUCTION

The goal of this research is to support cost-shared research on geothermal resources in North Dakota and South Dakota. Recent studies have shown that a large, accessible geothermal resource base is present in both North Dakota and South Dakota but the detailed nature of the resource is not well understood. A comprehensive assessment of the geothermal resources in these states will be completed which extends the previous studies by the Principal Investigator and by others, and specifically addresses problems and areas of interest discovered in earlier studies.

2.0 SCOPE

The database of accurate temperature and temperature gradient data for North Dakota and South Dakota will be increased by logging available deep and shallow wells. Bottom-hole temperature (BHT) data will be analyzed to look for high and low heat-flow zones similar to occurrences reported in Saskatchewan and Manitoba, Canada, and a systematic evaluation of the thermal conductivities of rocks in the Williston Basin will be conducted. The grantee will drill five heat-flow holes in North Dakota and five heat-flow holes in South Dakota to investigate hydrologic disturbances and sources of high heat flow in additional detail. All the new data resulting from these tasks will be integrated into the geothermal database, and analyzed and interpreted to complete a geothermal resource assessment which includes calculations of the production potential for all potential geothermal aquifers in the two-state study area. Finally, the results of the study will be disseminated at the state level by meetings with appropriate state offices and service agencies, and through professional publications and presentations. This research will be accomplished in a period of 24 months.

3.0 APPLICABLE DOCUMENTS

The research described herein is abstracted from a proposal titled "Stratabound Geothermal Resources in North Dakota and South Dakota", dated June 18, 1987, and submitted by the North Dakota Mining and Mineral Resources Research Institute. This proposal was submitted in response to DOE-ID Program Research and Development Announcement (PRDA) for State Geothermal Research and Development - PRDA No. DE-PR07-87ID12662.

4.0 TECHNICAL TASKS

The following tasks will be accomplished under this Grant.

4.1 Obtain temperature and temperature-gradient data by logging available deep and shallow wells which become available as holes of opportunity i.e., oil and gas exploration wells, deep water wells, scientific test holes, or holes drilled for mineral exploration.

4.2 Analyze bottom-hole temperature data to look for high and low heat-flow zones similar to the cases reported in Saskatchewan and Manitoba, Canada.

4.3 Conduct a systematic evaluation of the thermal conductivities of rocks in the Williston Basin.

4.4 Drill five heat-flow holes in North Dakota to investigate the hydrologic disturbances described in task 4.2.

4.5 Drill five heat-flow holes in South Dakota to investigate the sources of high heat flow in central and southern South Dakota.

4.6 Assimilate available data and calculate production potential for all potential geothermal aquifers in the study area.

4.7 Assimilate stratigraphic and hydrologic data into the geothermal database.

4.8 Analyze and interpret the data to complete the geothermal resource assessment.

4.9 Disseminate the results of this research at the state and national levels through meetings with appropriate state agencies and presentations at professional meetings.

5.0 REPORTS, DATA AND OTHER DELIVERABLES

5.1 Management Records - Reports will be due as indicated on the Federal Assistance Reporting Checklist and the Report Distribution List.

5.2 Final Report - A detailed final technical report will be prepared which will describe all new temperature data, data reduction methods, computer algorithms used, data tables, maps, and methods of research. A draft final report will be submitted for review and comment not less than 45 days prior to the scheduled delivery of the final report.

6.0 SPECIAL CONSIDERATIONS

The North Dakota Geological Survey and the South Dakota Geological Survey will be involved in this project through the direct participation of geologists from their staffs. A N.D.G.S. logging truck with a continuous temperature logging system will be available for this study.

wp/Thorne

REPORT DISTRIBUTION LIST

Grant No. DE-FG07-88ID12736

Report/Plan	Form No.	Frequency	No. of Copies	Address
Federal Assistance Management Summary Report	EIA-459E	Q	1,1,1,1,1	a,b,c,d,e
Notice of Energy RD&D	DOE 538	O	1,1	a,f
Technical Progress Report	EIA-459F	Q	1,1,1,1	a,b,d,e
Topical Report	N/A	A	1,4,1,1	a,b,d,e
Final Technical Report	N/A	F	1,4,1,1	a,b,d,e
Financial Status Report	SF-269	F	1,1,1	a,b,c

LIST OF ADDRESSEES

a. U.S. Department of Energy
785 DOE Place
Idaho Falls, ID 83402
Attn: Trudy A. Thorne

b. Same as above
Attn: Kenneth J. Taylor

c. Same as above
Attn: Earl Jones

d. U.S. Department of Energy
Forrestal Bldg., CE-342
1000 Independence Ave, SW
Washington, DC 20585
Attn: ~~Lew Pratsch~~ Marshall Reed

e. University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295
Attn: Howard Ross

f. U.S. Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, TN 37830

Grant No. DE-FG07-88ID12736
Part V - Reporting Requirements

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE REPORTING CHECKLIST

FORM EIA 459A
(10-80)

FORM APPROVED
OMB NO 1900-0127

1. Identification Number:
DE-FG07-88ID12736

2. Program/Project Title:
Geothermal Research & Development Asst.

3. Recipient:
North Dakota Mining & Mineral Resource Institute

4. Reporting Requirements:

	Frequency	No. of Copies	Addressees
PROGRAM/PROJECT MANAGEMENT REPORTING			
[ ] Federal Assistance Milestone Plan			
[ ] Federal Assistance Budget Information Form			
[X] Federal Assistance Management Summary Report	Q	1,1,1,1,1	a,b,c,d,e
[ ] Federal Assistance Program/Project Status Report			
[X] Financial Status Report, OMB Form 269	F	1,1,1	a,b,c
TECHNICAL INFORMATION REPORTING			
[X] Notice of Energy RD&D	O	1,1	a,f
[X] Technical Progress Report	Q	1,1,1,1	a,b,d,e
[X] Topical Report	A	1,4*,1,1	a,b*,d,e
[X] Final Technical Report	F	1,4*,1,1	a,b*,d,e

FREQUENCY CODES AND DUE DATES:

A - As Necessary; within 5 calendar days after events
F - Final; 90 calendar days after the performance of the effort ends.
Q - Quarterly; within 30 days after end of calendar quarter or portion thereof.
O - One time after project starts; within 30 days after award.
X - Required with proposals or with the application or with significant planning changes.
Y - Yearly; 30 days after the end of program year. (Financial Status Reports 90 days).
S - Semiannually; within 30 days after end of program fiscal half year.

5. Special Instructions:
*3 copies plus a camera-ready copy

6. Prepared by: (Signature and Date)
[signature] 1-22-88

7. Reviewed by: (Signature and Date)
[signature] 1/22/88

February 13, 1991

Dr. Wil Gosnold
Dept. of Geology and Geological Engineering
University of North Dakota
Box 8068, University Station
Grand Forks, ND 58202

Dear Wil:

I have completed a quick review of your draft final report "Stratabound Geothermal Resources in the Northern Great Plains" and am returning the same with comments in the margins.

Wil, I have the impression that this is a first draft, rather than a near final version of the report. The description of the technical work and the results are well written, but there are a number of typos, errors, reference problems that detract from the quality of the report at this stage. Please request a No Cost Time Extension from DOE/ID if you need additional time to clean up illustrations, text and tables. Since you have already exercised the option to award yourself (UND) one time extension, you would have to formally request an additional one before February 28.

Some additional comments on the draft report are attached. Please call me for any clarification.

Sincerely,

Howard Ross
Project Manager, SCP

Review Comments

1. Include DOE Disclaimer statement.

2. Report Structure. As presently written, the report structure is somewhat unusual. Generally an abstract and/or Executive Summary would proceed the Table of contents but page numbering begins with the Introduction. A copy of a more typical structure is enclosed.

3. The Min chu report is a good in-depth report that puts some reality into the 36 exjoule resource estimate. It should be introduced as a companion report, referenced, and briefly summarized at an appropriate place in your report.

4. Could you produce a short abstract to aid in NTIS description? Perhaps a 1 page abstract, with the present Summary just before Conclusions, would be a better structure.

5. For those of us less familiar with the geologic setting of the Northern Great Plains, it would be useful to have a one paragraph to 1 page description of the geology to accompany Table 1, and perhaps a simplified geologic cross section (E-W) indicating major aquifers, scale, depths, etc. You speak of "similar geologic and hydrologic features" but do not elaborate very much.

6. The Results chapter seems too terse and less readable than it could because of the structure which adresses objectives. You could accomplish the same thing with a separate chapter for A, B, and C, deleting the Objective lead in, and introducing each topic with a few sentences of flowing text. Or alternatively go with a single chapter but three subheadings.

7. Since the new DOE funded drill holes were an important part of the project they warrant a full paragraph or more of discussion, with reference to location map and perhaps a table summarizing depth, maximum temperature, dT/dZ, etc.

8. Please be sure to include a list of Figure captions, or captions with figures if they are interspersed with text (preferable). Review for typos, etc. on figures.

9. List of Tables.

10. Make sure each appendix has a cover page, introduction and location data if appropriate (i.e. map for drill hole locations).

11. The Min Chu report has many of the problems I noted earlier. Please review comments in the text and make sure report is carefully proofread by editor before going to print. See comments in text.

MEMORANDUM

TO: Ken Taylor

FROM: Howard Ross

DATE: Sept 27, 1989

Here are the pages of the North Dakota grant which seem to be affected by the requested contract modification. I have noted the items which are to be changed and suggested some new verbage.

The proposed contract modifications seem valid. The no cost time extension will allow Dr. Gosnold and two co-workers time to present their studies at the 1990 International Geothermal Energy Symposium, giving the widest possible exposure to this DOE sponsored work. Shifting three of the drill holes to South Dakota is warranted because of new information on the hydrology and heat flow both in North Dakota and South Dakota. I recommend that the requested modifications be approved.

If the contract modifications are approved by DOE it would be most advantageous to Dr. Gosnold, the subcontract driller, and the project in general if verbal approval to proceed with these changes could be given by telephone to Dr. Gosnold as soon as possible. This would avoid additional drilling standby costs and may possibly avoid future weather-related problems.

Howard

Howard P. Ross
Project Manager

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law PL 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Energy Research, Development, and Demonstration Act of 1974

1. PROJECT TITLE
Stratabound Geothermal Resources in North Dakota and South Dakota

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
North Dakota Mining and Mineral Resources Inst.
University of North Dakota, P. O. Box 8103
University Station, Grand Forks, ND 58202

4. INSTRUMENT NO. DE-FG07-88ID12736

5. AMENDMENT NO.

6. BUDGET PERIOD FROM: 4/1/88 THRU: 3/31/89

7. PROJECT PERIOD FROM: 4/1/88 THRU: 3/31/90
9/30/90

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
William D. Gosnold (701) 777-2631

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Alice Brekke (701) 777-5160

10. TYPE OF AWARD
☒ NEW ☐ CONTINUATION ☐ RENEWAL ☐ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Kenneth J. Taylor (208) 526-9063
U.S. DOE, Idaho Operations Office
785 DOE Place, Idaho Falls, Idaho 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Trudy A. Thorne (208) 526-9519
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, Idaho 82402

Change to Ken Osborne ?

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ INDIVIDUAL
☐ LOCAL GOV'T ☒ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
89X0224.91	AM1510000	410	

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ 194,814
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-
(4) DOE Share of Total Approved Budget	$ 194,814
(5) Recipient Share of Total Approved Budget	$ 44,195
(6) Total Approved Budget	$ 239,009

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 194,814
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 194,814

17. TOTAL ESTIMATED COST OF PROJECT $ 239,009

(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ______ *(Date)* ______

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☒ B (Grants) or ☐ C (Cooperative Agreements).

d. Application/proposal dated June 18, 1987, ☐ as submitted ☒ with changes as negotiated

19. REMARKS

This Grant consists of this NFAA (DOE Form 4600.1), Part I - Budget Plan; Part II - Special Conditions; Part III - General Conditions; Part IV - Statement of Work; Part V - Reporting Requirements. DOE Financial Assistance Rules (10 CFR Part 600), OMB Circular A-110 and OMB Circular A-21 are hereby incorporated by reference.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Alex Kotch 03-31-88
(Signature of Authorized Recipient Official) *(Date)*

Alex Kotch, Director-Office of Research and Program Development
(Name)

(Title)

21. AWARDED BY

J P Anderson 3/30/88
(Signature) *(Date)*

J. P. Anderson, Contracting Officer
(Name)

Chief, R&D Contracts Branch
(Title)

Grant No. DE-FG07-88ID12736
Part I - Budget Plan

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA 459C (10 80) | FORM APPROVED OMB No. 1900-0127

1. Program/Project Identification No.	2. Program/Project Title	
DE-FG07-88ID12736	Stratabound Geothermal Resources in North & South Dakota	
3. Name and Address: North Dakota Mining and Mineral Resources Research Insti. Box 8103 University Station Grand Forks, ND 58202		4. Program/Project Start Date: April 1, 1988 5. Completion Date: March 31, 1990 Sept. 30, 1990

SECTION A - BUDGET SUMMARY

Grant Program, Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non-Federal (f)	New or Revised Budget: Total (g)
1. 12693	81.087	$	$	$	$	$
2. First Year				118,887	21,666	140,553
3. Second Year				75,927	22,529	98,456
4.						
5 TOTALS		$	$	$	$	$

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	Grant Program, Function or Activity: DOE Cost Share (1) First Year	(2) Second Year	N. Dakota Cost Share (3) First Year	(4) Second Yr.	Total (5)
a. Personnel	$ 28,803	$ 29,917	$ 7,997	$ 8,313	$ 75,030
b. Fringe Benefits	6,913	7,180	1,919	1,995	18,007
c. Travel	7,606	7,606			15,212
d. Equipment					
e. Supplies	1,550	1,550			3,100
f. Contractual	40,000				40,000
g. Construction		N. Dak. – S. Dak. –	6,066 5,684	6,309 5,912	12,375 11,596
h. Other Research Support 69% of Direct Labor	19,874	20,643			40,517
i. Total Direct Charges	104,746	66,896	21,666	22,529	215,837
j. Indirect Charges 13.5%	14,141	9,031			23,172
k. TOTALS	$ 118,887	$ 75,927	$ 21,666	$ 22,529	$ 239,009
7. Program Income	$	$	$	$	$

NOTE: This Grant is for a two-year period at a total estimated DOE cost of $194,814 and total estimated Grantee cost of $44,195 for a total of $239,009.

This will be funded as follows:

First Year:	DOE -	$118,887	Grantee -	$21,666
Second Year:	DOE -	75,927	Grantee -	22,529
		$194,814		$44,195

This allocation may change somewhat - I don't know how much.

STATEMENT OF WORK

1.0 INTRODUCTION

The goal of this research is to support cost-shared research on geothermal resources in North Dakota and South Dakota. Recent studies have shown that a large, accessible geothermal resource base is present in both North Dakota and South Dakota but the detailed nature of the resource is not well understood. A comprehensive assessment of the geothermal resources in these states will be completed which extends the previous studies by the Principal Investigator and by others, and specifically addresses problems and areas of interest discovered in earlier studies.

2.0 SCOPE

The database of accurate temperature and temperature gradient data for North Dakota and South Dakota will be increased by logging available deep and shallow wells. Bottom-hole temperature (BHT) data will be analyzed to look for high and low heat-flow zones similar to occurrences reported in Saskatchewan and Manitoba, Canada, and a systematic evaluation of the thermal conductivities of rocks in the Williston Basin will be conducted. The grantee will drill five heat-flow holes in North Dakota and five heat-flow holes in South Dakota to investigate hydrologic disturbances and sources of high heat flow in additional detail. All the new data resulting from these tasks will be integrated into the geothermal database, and analyzed and interpreted to complete a geothermal resource assessment which includes calculations of the production potential for all potential geothermal aquifers in the two-state study area. Finally, the results of the study will be disseminated at the state level by meetings with appropriate state offices and service agencies, and through professional publications and presentations. This research will be accomplished in a period of 24 months.

3.0 APPLICABLE DOCUMENTS

The research described herein is abstracted from a proposal titled "Stratabound Geothermal Resources in North Dakota and South Dakota", dated June 18, 1987, and submitted by the North Dakota Mining and Mineral Resources Research Institute. This proposal was submitted in response to DOE-ID Program Research and Development Announcement (PRDA) for State Geothermal Research and Development - PRDA No. DE-PR07-87ID12662.

The grantee will drill at least eight heat flow holes in South Dakota. Two additional heat flow holes will be drilled ~~either~~ in North Dakota, ~~or in South Dakota~~. All 10 holes will investigate hydrologic disturbances and sources of high heat flow in additional detail.

4.0 TECHNICAL TASKS

The following tasks will be accomplished under this Grant.

4.1 Obtain temperature and temperature-gradient data by logging available deep and shallow wells which become available as holes of opportunity i.e., oil and gas exploration wells, deep water wells, scientific test holes, or holes drilled for mineral exploration.

4.2 Analyze bottom-hole temperature data to look for high and low heat-flow zones similar to the cases reported in Saskatchewan and Manitoba, Canada.

4.3 Conduct a systematic evaluation of the thermal conductivities of rocks in the Williston Basin.

4.4 Drill five heat-flow holes in North Dakota to investigate the hydrologic disturbances described in task 4.2.

4.5 Drill five heat-flow holes in South Dakota to investigate the sources of high heat flow in central and southern South Dakota.

4.6 Assimilate available data and calculate production potential for all potential geothermal aquifers in the study area.

4.7 Assimilate stratigraphic and hydrologic data into the geothermal database.

4.8 Analyze and interpret the data to complete the geothermal resource assessment.

4.9 Disseminate the results of this research at the state and national levels through meetings with appropriate state agencies and presentations at professional meetings.

5.0 REPORTS, DATA AND OTHER DELIVERABLES

5.1 Management Records - Reports will be due as indicated on the Federal Assistance Reporting Checklist and the Report Distribution List.

5.2 Final Report - A detailed final technical report will be prepared which will describe all new temperature data, data reduction methods, computer algorithms used, data tables, maps, and methods of research. A draft final report will be submitted for review and comment not less than 45 days prior to the scheduled delivery of the final report.

4.5 Drill eight ~~seven~~ heat-flow holes in South Dakota to investigate the sources of high heat flow in central and Southern South Dakota.

4.4 Drill two heat-flow holes in North Dakota to investigate the hydrologic disturbances along the Billing's Nose, a deep structure in the Williston Basin.

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law PL 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Energy Research, Development, and Demonstration Act of 1974

1. PROJECT TITLE
Stratabound Geothermal Resources in North Dakota and South Dakota

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
North Dakota Mining and Mineral Resources Inst.
University of North Dakota, P.O. Box 8103
University Station, Grand Forks, ND 58202

4. INSTRUMENT NO. DE-FG07-88ID12736

5. AMENDMENT NO. M001

6. BUDGET PERIOD FROM: 4/1/88 THRU: 3/31/89

7. PROJECT PERIOD FROM: 4/1/88 THRU: 3/31/90

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
William D. Gosnold (701) 777-2631

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Alice Brekke (701) 777-5160

10. TYPE OF AWARD
☐ NEW ☐ CONTINUATION ☐ RENEWAL
☒ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Kenneth J. Taylor (208) 526-9063
U.S. DOE, Idaho Operations Office
785 DOE Place, Idaho Falls, ID 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Trudy A. Thorne (208) 526-9519
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ INDIVIDUAL
☐ LOCAL GOV'T ☒ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ -0-
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-
(4) DOE Share of Total Approved Budget	$ 194,814
(5) Recipient Share of Total Approved Budget	$ 44,195
(6) Total Approved Budget	$ 239,009

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 194,814
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 194,814

17. TOTAL ESTIMATED COST OF PROJECT $ 239,009
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ________ *(Date)* ________

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☐ C (Cooperative Agreements).

d. Application/proposal dated June 18, 1987, ☐ as submitted ☒ with changes as negotiated

19. REMARKS

SEE ATTACHMENT.......

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Alex Kotch 09-29-88
(Signature of Authorized Recipient Official) *(Date)*

~~Alex Kotch, Director Office of~~
Research and Program Development
(Name)
(Title)

21. AWARDED BY

J P Anderson 9/2/88
(Signature) *(Date)*

J. P. Anderson, Contracting Officer
(Name)
Chief, R&D Contracts Branch
(Title)

This modification revises the following:

Part II - Special Conditions, Section 1.f. Cost Share Arrangement, second and third sentence revised to read: All labor and fringe benefits for the Principal Investigator occurring during the academic year (August 15 - May 15) shall be paid by North Dakota Mining and Mineral Resources. All other labor and fringe benefits shall be paid by the Department of Energy.

Part V - Reporting Requirements, List of Addressees, d., change Lew Pratsch to Marshall Reed.

FORM EIA-459F
(10/80)

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE PROGRAM/PROJECT STATUS REPORT

FORM APPROVED
OMB No. 1900-0127

Rec 03/06 /89 WR

1. Program/Project Identification No.	2. Program/Project Title	3. Reporting Period
DE-FG07-88ID12736	Stratabound Geothermal Resources in ND & SD	10/1/88 through 12/31/88
4. Name and Address		5. Program/Project Start Date
North Dakota Mining and Mineral Resources Research Institute University of North Dakota, P.O. Box 8103, University Station Grand Forks, ND 58202		4/1/88
		6. Completion Date 3/31/90

7. Approach Changes

☒ None

8. Performance Variances, Accomplishments, or Problems

Calibration of divided-bar complete.

Plans for drilling are being formed.

Bottom-hole data set is inconclusive in identifying high heat flow zones - so far. Analysis is continuing.

☐ None

9. Open Items

☒ None

10. Status Assessment and Forecast

☒ No Deviation from Plan is Expected

11. Description of Attachments

☒ None

12. Signature of Recipient and Date	13. Signature of DOE Reviewing Representative and Date
W. D. Gosnold 3/8/89	

FORM EIA-459E
(10/80)

U.S. DEPARTMENT OF ENERGY
FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

FORM APPROVED
OMB No. 1900-0127

Page ___ of ___

1. Program/Project Identification No.	2. Program/Project Title	3. Reporting Period
DE-FG07-88ID12736	Stratabound Geothermal Resources in ND & SD	10/1/88 through 12/31/88

4. Name and Address	
North Dakota Mining and Mineral Resources Research Institute University of North Dakota, P.O. Box 8103, University Station Grand Forks, ND 58202	5. Program/Project Start Date: 4/1/88 6. Completion Date: 3/31/90

7. FY: 88
8. Months or Quarters: Quarters

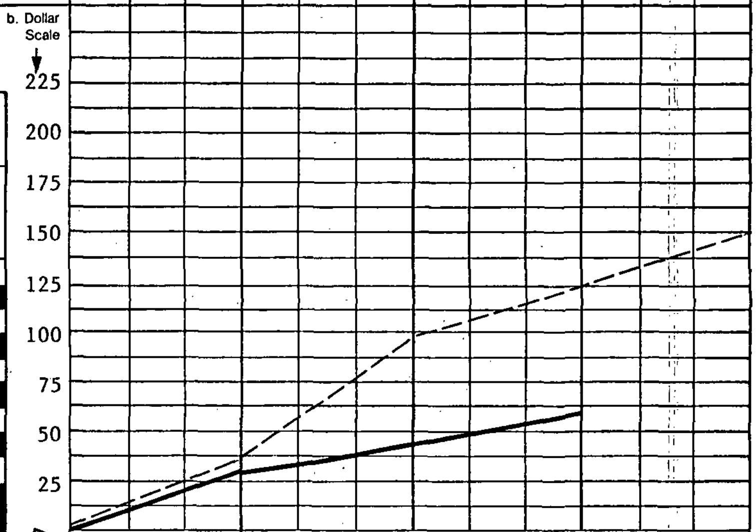
1st Quarter			2nd Quarter			3rd Quarter			4th Quarter		
A	M	J	J	A	S	O	N	D	J	F	M

9. Cost Status
a. Dollars Expressed in: Thousands
b. Dollar Scale

10. Cost Chart

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
	P	25	55	25	14	105	119
	A	25	16	9		50	
	P	5	5	5	6	15	21
	A	2	1	3		6	
	P						
	A						
	P						
	A						
Total P		30	60	30	20	120	140
Total A		27	17	12		56	
Variance		3	43	18		64	

P = Planned A = Actual

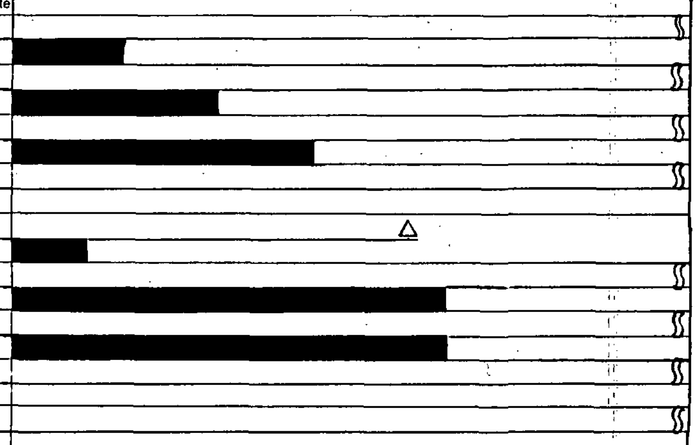


Cumulative Accrued Costs

	A	M	J	J	A	S	O	N	D	J	F	M
Planned			30			90			120			140
Actual			27			44			56			
Variance			3			46			64			

Total Planned Costs for Program/Project: $239,009.00

11. Major Milestone Status	Units Planned / Units Complete
4.1 Obtain Temp Data	P / C
4.2 Analyze bottom-hole data	P / C
4.3 Evaluate thermal conduct	P / C
4.4 Drill 5 holes in ND	P / C
4.5 Drill 5 holes in SD	P / C
4.6 Assimilate data & calculate	P / C
4.7 Assim. strat. & hydro data	P / C
4.8 Analyze & Interpret Data	P / C
4.9 Disseminate results	P / C
5.2 Final Report	P / C
	P / C
	P / C
	P / C
	P / C
	P / C
	P / C
	P / C



12. Remarks

13. Signature of Recipient and Date: William Gosnold 2/1/89

14. Signature of DOE Reviewing Representative and Date

Rec. Aug 5, '88

Submitted to GSA for the 1988 annual meeting

COINCIDENT HEAT FLOW, GRAVITY AND EROSIONAL ANOMALIES ALONG PRECAMBRIAN TERRANE BOUNDARIES IN SOUTH CENTRAL SOUTH DAKOTA

GOSNOLD, William D., Department of Geology and Geological Engineering, Univ. of North Dakota, Box 8068, Grand Forks, ND, 58202; SHURR, George. W., Dept. of Earth Science, St. Cloud State Univ., St. Cloud, MN 56301

A 100 mW m^{-2} heat flow anomaly coincides with a -50 mgal Bouguer gravity anomaly over a 40,000 km^2 area along the inferred boundary between the Precambrian Central Plains province (1.6 - 1.8 Ga) and the Precambrian Trans-Hudson Belt (1.8 - 1.9 Ga) in south central South Dakota. The geophysically anomalous area has undergone uplift and erosion in the late Tertiary. Hypotheses for origins of the anomalies include a radioactive batholith, advection of heat by flowing groundwater, and a mantle hot spot. We have modelled the geological and geophysical conditions that would develop from these sources and have designed tests to evaluate each hypothesis. The temperature-depth curves and geologic histories for each model have characteristics that are significantly different. A batholith 12 km thick with a density contrast of -120 kg m^{-3} and a heat generation of 10 W m^{-3} could generate both the gravity and heat flow anomalies. The T-D plot in the sedimentary section would be predictable and the Paleozoic and Cenozoic depositional histories of the thermally anomalous area would not differ from that of the surrounding area. T-D curves for the advection model would show significant variations in a vertical section and the history of the Cenozoic would be different from that of the surrounding area. The mantle hot spot would produce a distinct T-D curve, and the geologic history would show uplift and erosion during the Cenozoic as in the advection model. All three models have implications for involvement of Precambrian structures in recent crustal movements.

The data necessary to test these hypotheses include heat flow, geologic history, and basement geochemistry. These data could be generated from a series of holes drilled and continuously cored to basement.

ANALYSIS OF HEAT FLOW AND GROUNDWATER FLOW IN THE SOUTH DAKOTA GEOTHERMAL ANOMALY

William D. Gosnold, Jr.

Department of Geology and Geological Engineering
University of North Dakota
Grand Forks, ND 58202

Abstract

A geothermal anomaly with heat flow values ranging from 80 mW m^{-2} to about 130 mW m^{-2} extends over an area of about 40,000 km centered in southern South Dakota. The anomaly is caused by the thermal effects of a complex groundwater flow system which is driven by eastward sloping hydraulic gradients. Heat advection occurs due to upward fracture leakage near major stream valleys and due to confined, updip groundwater flow that has persisted for about 65 m.y.. Analysis of temperature-depth and gradient-depth curves from heat flow holes in the anomalous area indicates that upward fracture leakage may be significant only near gaining streams. Energy flux calculations suggest that the positive heat flow anomaly equals the heat sink caused by recharge of the regional groundwater system.

Introduction

Heat flow data have provided the basis for calculation of the geothermal energy contained in sedimentary strata in a number of geothermal resource assessments conducted under the auspices of the U. S. Department of Energy [Gosnold and Eversoll, 1982; Staveness and Steeples, 1982; Gosnold, 1984; Gosnold, 1987; New Mexico]. Studies indicating anomalous heat flow in the northern Great Plains [Blackwell, 1969; Sass et al., 1971; Combs and Simmons, 1973; Gosnold, 1985; 1988] have led to discovery of extensive low-temperature geothermal resources in Nebraska [Gosnold and Eversoll, 1982] and South Dakota [Gosnold, 1987]. Understanding the origins of the anomalous heat flow is a step toward better understanding of these stratabound geothermal resources. This paper deals with a continuing study of a large heat flow anomaly in parts of South Dakota and Nebraska.

The heat flow anomaly

Surface heat flow values exceed 80 mW m^{-2} over a 40,000 km^2 area in southern South Dakota and northern Nebraska. Conventional heat flow measurements with values ranging from 81 mW m^{-2} to 112 mW m^{-2} [Sass and Galanis, 1983; Gosnold, 1988] and several hundred temperature-gradient measurements made in water wells in South Dakota and Nebraska [Schoon and McGregor, 1974; Gosnold and Eversoll 1982] define the areal extent of the thermal anomaly (Figure 1). Temperature gradients in the anomalous area commonly exceed 100 K km^{-1} [Gosnold and Eversoll, 1982], and in the area west of the Missouri River in Gregory County, South Dakota temperature gradients exceed 130 K km^{-1} [Schoon and McGregor, 1974]. Thermal conductivities of the Mesozoic shales in which these anomalous gradients occur are about 1.2 W m^{-1} K^{-1} [Gosnold, 1988], thus heat flow values of greater than 150 mW m^{-2} may exist in certain areas.

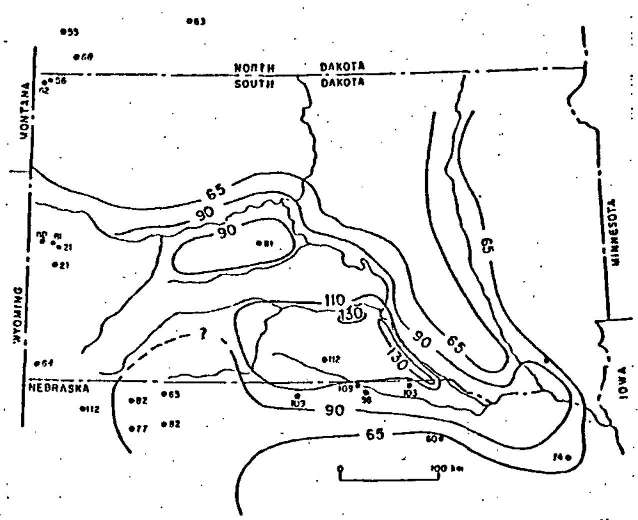


Figure 1. Heat flow contours in South Dakota and Nebraska based on conventional heat flow measurements, filled circles, and deduced from temperature gradient measurements by Schoon and McGregor [1974]. Heat flow data from Sass et al. [1971], Sass and Galanis [1983], and Gosnold [1988]. Heat flow values are given in mW m^{-2}.

Advective heat flow model

A working hypothesis is that the geothermal *anomaly results from heat advection due to gravity-*driven groundwater flow east of the Black Hills. The advective heat-flow system is caused by a hydraulic gradient that slopes downward to the east and causes upward groundwater flow in the discharge areas in south central South Dakota and north central Nebraska [Gosnold, 1988]. Two modes of heat advection are suggested to occur. Advection due to cross-formational flow through fractures toward the surface is suggested by the work of Bredehoeft et al. [1983]. This mode of advection could be particularly significant near gaining streams and other discharge areas. Advection due to confined groundwater flow within the Dakota, Minnelusa and Madison aquifers underlying the region is suggested by several hydrologic studies of [Schoon, 1971; Schoon and McGregor, 1974; Downey, 1986]. Heat advection due to updip groundwater flow occurs over the anomalous area and could account for most of the thermal anomaly.

Fracture leakage

The occurrence and magnitude of cross-formational flow from the Dakota aquifer through fractures in the overlying confining layers was deduced during an extensive study by J.D. Bredehoeft and colleagues and is summarized by Bredehoeft et al. [1983]. Vertical flow velocities computed by Bredehoeft et al [1983] range as high as 3×10^{-11} m s^{-1} (Fig. 2). Much of the region of upflow coincides with the heat flow anomaly except for the area west of the Keya Paha river on both sides of the South Dakota-Nebraska border.

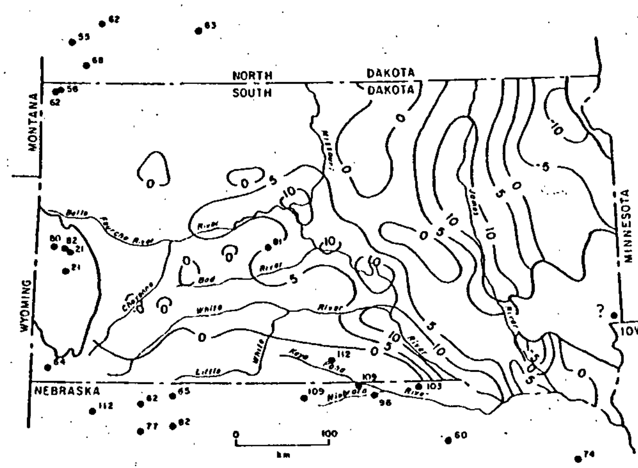


Figure 2. Contours of upward fracture-leakage velocity in 10^{-11} ft s^{-1}. Heat flow data are included for comparison.

A relationship between heat flow, water velocity, and distance of flow for a vertical one-dimensional system [Lachenbruch and Sass, 1977] may be used to calculate advection based on Bredehoeft et al.'s [1983] flow velocities as follows:

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Q_1 is heat flow at the base of the zone of flow, Q_2 is heat flow at the top, V is Darcy velocity in m s^{-1}, D is the length of the zone in meters, is density of the fluid in Kg m^{-3}, C_p is heat capacity of the fluid in W s Kg^{-1}, and K is thermal conductivity in W m^{-1} K^{-1}.

Other than flow velocity, the critical parameters for this model are depth to the Dakota aquifer, 1000 m in the west to about 500 m in the east, surface heat flow, 80-130 mW m^{-2}, and heat flow below the Dakota aquifer. To apply Eq. 1 to the anomalous area, two necessary conditions are that fracture spacing is sufficiently small for the thermal effects of fracture leakage to approximate that of homogeneous flow and that the duration of fracture leakage has been sufficient to approach steady-state conditions.

The best test for the existence of these conditions would be a series of heat flow holes drilled to the aquifer along a line perpendicular to the strike of a leaking fracture. This test is presently underway and results should be available by 1989. However, published data on fracture spacing combined with existing heat flow and temperature gradient data allow a preliminary analysis for the conditions.

Neuzil et al. [1984] analyzed the fracture density of the system and concluded that the likely average spacing of fractures is of the order of 100-1000 m. The duration of flow in a fracture system is uncertain without specific data on the thermal structure around a fracture. However, it is inferred from the work of Bredehoeft et al [1983] (see Fig. 2) that much of the present upward fracture leakage occurs in and near modern stream valleys. If it can be assumed that the valleys have become established since the Wisconsinan glaciation, the duration of flow could be of the order of 10,000 y. A series of numerical models using finite differences were computed for isolated fractures with time durations from greater than 2000 y. to 10,000 y. The results (Figure 3) indicate that for durations as long as 10,000 y, fractures spaced more than 100 m apart would produce heat flow patterns which vary systematically with depth and distance from the fractures. Although, these models do not test for the thermal structure that would evolve from a series of parallel fractures, it can be inferred that Eq. 1 should give accurate results only where fracture spacings are of the order of tens of meters and the flow duration has been of the order of 10^4 y.

Applying Eq. 1 to a region within 10's of meters from the fracture predicts that vertical water flow velocities of the order of 10^{-9}-10^{-10} m s^{-1} could produce a surface heat flow anomaly of greater than 120 mW m^{-2} with a heat flow value of 60 mW m^{-2} below the advective zone and an effective thermal conductivity of 1.2 W m^{-1} K^{-1} for the Cretaceous shales [Gosnold, 1988]. However, these velocities are 1-2 orders of magnitude greater than the velocities computed for the vertical flow by Bredehoeft et al. [1983]. This result suggests that fracture leakage from the Dakota sandstone to the surface would account for only half the amplitude of the heat flow anomaly in central South Dakota.

An important aspect of the numerical models used to produce Figure 3 is that heat flow near the

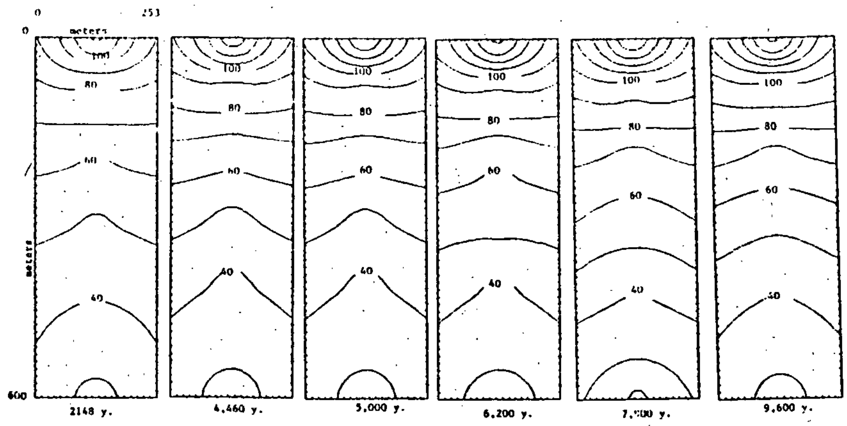

Figure 3. Heat flow contours around a 700 meter vertical crack at different times after the onset of vertical water flow at a velocity of 3×10^{-9} m s^{-1}. Heat flow is increased dramatically near the surface and is reduced near the water source at the bottom of the crack.

surface is increased but heat flow near the base of the fracture is reduced. This result is a necessary consequence of maintaining an energy balance in the groundwater flow system. No energy is actually introduced by the groundwater flow, it is simply redistributed. Predictions of the numerical models differ in this respect from those of the one-dimensional, steady-state condition predicted by Eq. 1.

Temperature gradient curves from heat flow measurements could provide a test for the fracture-leakage model. However, only one of the heat flow holes lies within the region of vertical flow identified by Bredehoeft et al [1983]. Eq. 1 and the numerical models predict that heat flow should vary as a function of the vertical length of groundwater flow. Thus, for constant conductivity and groundwater flow velocity, the magnitude of the heat flow anomaly should vary systematically in a drill hole. This variation would be apparent in the temperature - depth and gradient - depth plots with upward flow corresponding to a decreasing temperature gradient and is shown in theory in the plot labelled THEORETICAL in Figure 4.

Inspection of the temperature-depth and gradient-depth plots from heat flow sites (Figure 4) suggests that none of the sites lie in regions affected by fracture leakage. Generally, this interpretation agrees with the map of Bredehoeft et al. [1983]. The only exception is the site near Hayes in central South Dakota which lies on the 5 ft s^{-1} contour line but shows no effects of fracture leakage.

On the basis of the mapped extent of fracture leakage, it appears that upward leakage occurs primarily in and near stream valleys such as the Missouri, Cheyenne, White and James rivers. All but the James river valley, which lies in the flat bed of the James lobe of the Wisconsinan glaciation, are deeply incised and have locally steep hydraulic gradients. Thus, most of the heat advection due to variation would be apparent in the temperature-depth and gradient - depth plots with upward flow corresponding to a decreasing temperature gradient and is shown in theory in the plot labelled THEORETICAL in Figure 4. fracture leakage may be confined to the areas around the stream valleys.

Confined groundwater flow

The heat flow anomaly in north-central Nebraska and south-central South Dakota, where no cross-formational groundwater flow was computed by Bredehoeft et al. [1983], as well as about half of the heat flow anomaly in the fracture leakage zones could be caused by updip flow in as many as three regional aquifers. Water flow velocities of approximately 2×10^{-7} to 1.9×10^{-8} m s^{-1} were calculated for confined flow in the Madison and Dakota aquifers in the South Dakota by Downey [1986]. Water flow velocities for the Minnelusa aquifer, which is more than twice as thick as the Madison and Dakota aquifers in the study area and has transmissivity values equal to those of the Madison aquifer [Downey, 1986], were not included in Downey's [1986] study. However, the similarities in transmissivity, hydraulic gradient and recharge areas between the Minnelusa, Dakota and Madison aquifers suggest that flow velocities in the Minnelusa should be similar to those in the Madison and Dakota aquifers.

Heat advection by updip flow of groundwater within the Dakota, Minnelusa and Madison aquifers was computed using a finite difference model. The calculations show that velocities of the order of 6-7 $\times 10^{-8}$ m s^{-1} produce anomalous surface heat flow values of the order of 80 to 100 mW m^{-2}. These values would generate the observed regional anomaly, and would combine with advection due to fracture leakage to generate the localized, high values of 130 mW m^{-2}. The models for fracture-leakage and updip flow in the suggest that both modes of advection contribute to the heat flow anomaly.

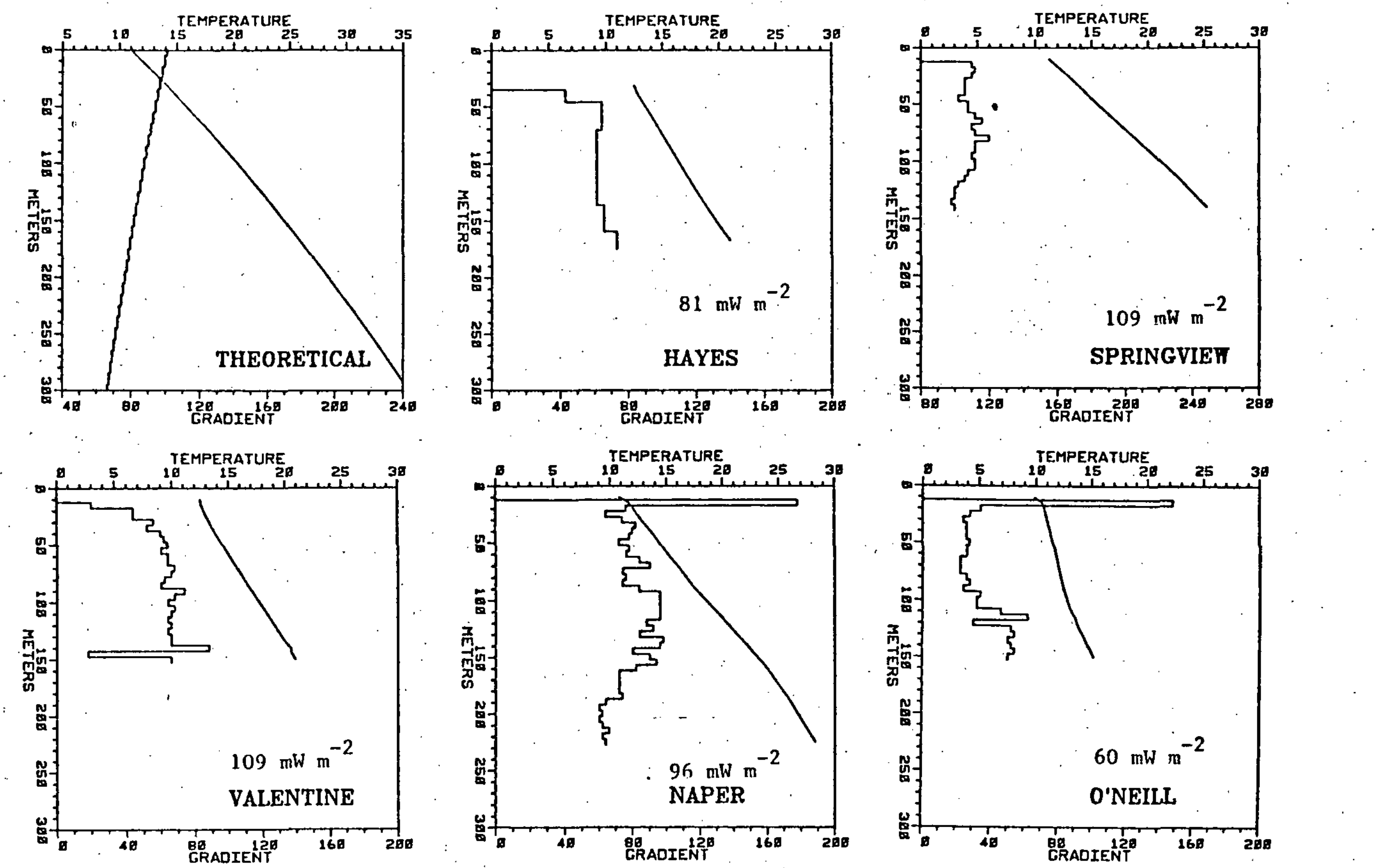

Figure 4. Temperature-depth and gradient-depth curves from northern Nebraska and central South Dakota. The plot labelled THEORETICAL is predicted from Eq. 1. and shows how the temperature gradient would decrease with depth in a region of homogeneous upward groundwater flow. The plot labelled Hayes is from Sass and Galanis [1983] and lies on the 5 x 10 $^{-11}$ ft s^{-1} contour line in Fig. 2. Locations of the holes can be matched to the heat flow values printed above the name.

Energy balance

An important aspect of the advection model is that the high heat flow due to upward water movement must be balanced by low heat flow due to downward water movement. Conceptually, low heat flow should occur in the recharge area in and around the Black Hills. The concept is empirically supported by heat flow values of about 20 mW m^{-2} (see Figure 1) reported for two localities in the Black Hills [Sass et al, 1971]. The anomalous heat flow component for these two low values is estimated to be about- 70 mW m^{-2} by subtracting the low values from the high values.

Determination of the quantity of anomalous energy flux in the area would require tens-of-thousands of heat flow holes. However, a reasonable estimate can be calculated from the product of the average heat flow and the area of the anomaly. The positive anomaly of about 40 mW m^{-2} extends over an area of 40,000 km^2 quantity and is of the order of 1.6 GW. The negative anomaly of about -70 mW m^{-2} extends over the crystalline outcrops and aquifer outcrops around the eastern side of the Black Hills. A lesser negative anomaly of about -60 mW m^{-2} is computed for the descending limb of the of the groundwater flow systems in the Kennedy Basin. The recharge area for the aquifers is varies in character in that most of the recharge comes from streams that cross outcrops of the aquifers and lesser amounts of recharge come from precipitation [Downey, 1986]. The area of groundwater recharge in the crystalline rocks is also difficult to estimate. However, for recharge from the aquifer outcrops and from the crystalline rocks, a total recharge area of only about 8,600 km^2 and a negative heat flow component of 70 mW m^{-2} would generate an anomalous energy flux of about -0.6 GW. The area of down dip flow east of the Black Hills is calculated from the finite difference model to generate an anomalous heat flow of - 1.0 GW. Thus in general terms, the energy flux is balanced with about -1.6 GW in the recharge area and +1.6 GW in the anomalous area.

Conclusions

The heat flow anomaly is caused by advection of heat in upward flowing groundwater both by cross-formational flow through fractures and by updip flow in regional aquifers. Heat advection from flow in regional aquifers. Heat advection from updip flow occurs throughout the area, but cross-formational flow through fractures may occur only near gaining streams. The magnitude of anomalous heat flow due to fracture leakage reaches about 50 mW m^{-2} near gaining streams and the magnitude of anomalous heat flow due to updip flow is about 40 mW m^{-2} in most of the area. These values of anomalous heat flow cause surface heat flow values of the order of 100 - 130 mW^{-2}. The physical conditions that control regional groundwater flow system have existed for about 65 M.Y.

Acknowledgements

The field and laboratory work in this study were supported in part by Department of Energy grants DE-AS07-79ET27205 and DE-FG07-85ID12606, and NSF grant EAR-8417305. Equipment used in temperature gradient measurements, thermal conductivity measurements and other logistical support were provided by the Geothermal Laboratory at Southern Methodist University. D. Becker, L. Carter, D. Hanson, and J. Gibbens assisted in logging temperatures. D. Eversoll facilitated drilling and sample collecting in all holes in Nebraska. R. Baker of Burton, Nebraska generously allowed continued drilling and temperature logging at the one site that provided the initial incentive for this study.

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In May and June, the South Dakota Geological survey drilled two holes for geological information and cased them for heat flow measurements. The holes were drilled as part of ongoing geological investigations by the South Dakota Geological Survey and completing them as heat flow holes is a bonus for this investigation. The South Dakota Geological Survey funded drilling of the holes and the D.O.E. Geothermal grant funded casing the holes. This cooperative work may increase the number of heat flow holes completed in South Dakota as part of this study from five to seven.

Also in June, the South Dakota Geological Survey alerted the P.I. to a geothermal well drilled by a rancher near White River, South Dakota, in early June. The field crew from UND visited the site and, after waiting for casing operation to be completed, measured a temperature of 69.5°C (158°F) in the Dakota Formation at a depth of 580 meters (1902 ft).

In May, both Chu and Gosnold submitted papers to the Geothermal Resources Council for the annual meeting to be held in San Diego in October 1988. Both papers have been accepted. Chu will make an oral presentation of his paper and Gosnold will make both an oral and poster presentation of his paper. Chu's paper focuses on theory of analysis of geothermal reservoirs and Gosnold's paper is concerned with the origin of the heat flow anomaly in South Dakota. Copies of the papers are attached.

Also in May, Gosnold collaborated with George Schurr, Department of Earth Sciences, St. Cloud State University, to submit an abstract to the Geological Society of America for the annual meeting to be held in Denver in November 1988. The abstract focuses on a proposal for deep drilling to test hypotheses for the origins of coincident geothermal, gravity, and erosional anomalies in South Dakota. A copy of the abstract is attached.

Complete sections [1] through [7] below

[1] TYPE ABSTRACT within blue lines — they're absolute! Mail flat, reinforced.

№ 9426

COINCIDENT HEAT FLOW, GRAVITY AND EROSIONAL ANOMALIES ALONG PRECAMBRIAN TERRANE BOUNDARIES IN SOUTH CENTRAL SOUTH DAKOTA

GOSNOLD, William D., Department of Geology and Geological Engineering, Univ. of North Dakota, Box 8068, Grand Forks, ND, 58202; SHURR, George. W., Dept. of Earth Science, St. Cloud State Univ., St. Cloud, MN 56301

A 100 mW m^{-2} heat flow anomaly coincides with a -50 mgal Bouguer gravity anomaly over a 40,000 km^2 area along the inferred boundary between the Precambrian Central Plains province (1.6 - 1.8 Ga) and the Precambrian Trans-Hudson Belt (1.8 - 1.9 Ga) in south central South Dakota. The geophysically anomalous area has undergone uplift and erosion in the late Tertiary. Hypotheses for origins of the anomalies include a radioactive batholith, advection of heat by flowing groundwater, and a mantle hot spot. We have modelled the geological and geophysical conditions that would develop from these sources and have designed tests to evaluate each hypothesis. The temperature-depth curves and geologic histories for each model have characteristics that are significantly different. A batholith 12 km thick with a density contrast of -120 kg m^{-3} and a heat generation of 10 μW m^{-3} could generate both the gravity and heat flow anomalies. The T-D plot in the sedimentary section would be predictable and the Paleozoic and Cenozoic depositional histories of the thermally anomalous area would not differ from that of the surrounding area. T-D curves for the advection model would show significant variations in a vertical section and the history of the Cenozoic would be different from that of the surrounding area. The mantle hot spot would produce a distinct T-D curve, and the geologic history would show uplift and erosion during the Cenozoic as in the advection model. All three models have implications for involvement of Precambrian structures in recent crustal movements.

The data necessary to test these hypotheses include heat flow, geologic history, and basement geochemistry. These data could be generated from a series of holes drilled and continuously cored to basement.

[2] CATEGORIZE ALL ABSTRACTS —Check ONE discipline below in which reviewers would be best qualified to evaluate this abstract.

- ☐ 1 archaeological geology
- ☐ 2 coal geology
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- ☐ 4 engineering geology
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- ☐ 6 general geology
- ☐ 7 geochemistry
- ☐ 8 geology education
- ☐ 9 geomorphology
- ☐10 geophysics
- ☐11 geoscience information
- ☐12 glacial geology
- ☐13 history of geology
- ☐14 hydrogeology
- ☐15 marine geology
- ☐16 micropaleontology
- ☐17 mineralogy/crystallography
- ☐18 oceanography
- ☐19 paleontology/paleobotany
- ☐20 petroleum geology
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- ☐22 petrology, igneous
- ☐23 petrology, metamorphic
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- ☐26 Precambrian geology
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[3] TYPES OF SESSIONS AVAILABLE

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☐ This abstract was invited for the symposium titled

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(1) SPECIAL—THEME SESSION, ANNUAL MEETING ONLY. I would like this abstract considered for oral presentation at the following Theme Session for the Annual Meeting, Denver, 1988.

- ☐ 1 Diagenesis of lacustrine rocks
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Topic ~~Tectonics Geophysics~~

Your name ~~Will Gosnold~~

Telephone (late June/early July) ~~701 777-2631~~

[6] SPEAKER'S IDENTITY AND MAILING ADDRESS

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ANALYSIS OF HEAT FLOW AND GROUNDWATER FLOW IN THE SOUTH DAKOTA GEOTHERMAL ANOMALY

William D. Gosnold, Jr.

Department of Geology and Geological Engineering
University of North Dakota
Grand Forks, ND 58202

Abstract

A geothermal anomaly with heat flow values ranging from 80 mW m^{-2} to about 130 mW m^{-2} extends over an area of about 40,000 km centered in southern South Dakota. The anomaly is caused by the thermal effects of a complex groundwater flow system which is driven by eastward sloping hydraulic gradients. Heat advection occurs due to upward fracture leakage near major stream valleys and due to confined, updip groundwater flow that has persisted for about 65 m.y.. Analysis of temperature-depth and gradient-depth curves from heat flow holes in the anomalous area indicates that upward fracture leakage may be significant only near gaining streams. Energy flux calculations suggest that the positive heat flow anomaly equals the heat sink caused by recharge of the regional groundwater system.

Introduction

Heat flow data have provided the basis for calculation of the geothermal energy contained in sedimentary strata in a number of geothermal resource assessments conducted under the auspices of the U. S. Department of Energy [Gosnold and Eversoll, 1982; Staveness and Steeples, 1982; Gosnold, 1984; Gosnold, 1987; New Mexico]. Studies indicating anomalous heat flow in the northern Great Plains [Blackwell, 1969; Sass et al., 1971; Combs and Simmons, 1973; Gosnold, 1985; 1988] have led to discovery of extensive low-temperature geothermal resources in Nebraska [Gosnold and Eversoll, 1982] and South Dakota [Gosnold, 1987]. Understanding the origins of the anomalous heat flow is a step toward better understanding of these stratabound geothermal resources. This paper deals with a continuing study of a large heat flow anomaly in parts of South Dakota and Nebraska.

The heat flow anomaly

Surface heat flow values exceed 80 mW m^{-2} over a 40,000 km^2 area in southern South Dakota and northern Nebraska. Conventional heat flow measurements with values ranging from 81 mW m^{-2} to 112 mW m^{-2} [Sass and Galanis, 1983; Gosnold, 1988] and several hundred temperature-gradient measurements made in water wells in South Dakota and Nebraska [Schoon and McGregor, 1974; Gosnold and Eversoll 1982] define the areal extent of the thermal anomaly (Figure 1). Temperature gradients in the anomalous area commonly exceed 100 K km^{-1} [Gosnold and Eversoll, 1982], and in the area west of the Missouri River in Gregory County, South Dakota temperature gradients exceed 130 K km^{-1} [Schoon and McGregor, 1974]. Thermal conductivities of the Mesozoic shales in which these anomalous gradients occur are about 1.2 W m^{-1} K^{-1} [Gosnold, 1988], thus heat flow values of greater than 150 mW m^{-2} may exist in certain areas.

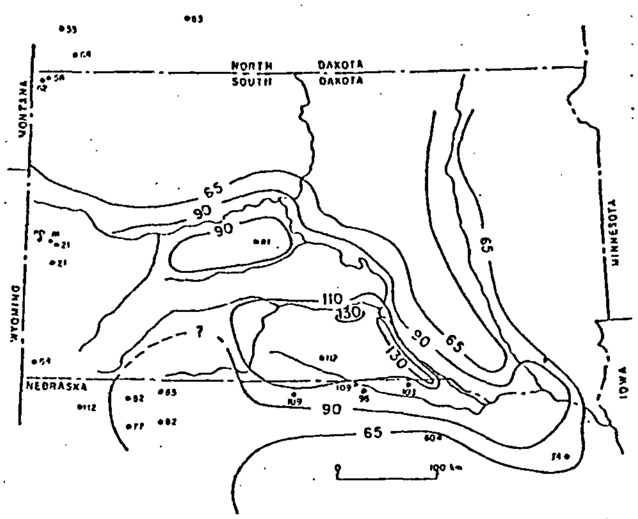

Figure 1. Heat flow contours in South Dakota and Nebraska based on conventional heat flow measurements, filled circles, and deduced from temperature gradient measurements by Schoon and McGregor [1974]. Heat flow data from Sass et al. [1971], Sass and Galanis [1983], and Gosnold [1988]. Heat flow values are given in mW m^{-2}.

Advective heat flow model

A working hypothesis is that the geothermal anomaly results from heat advection due to gravity-driven groundwater flow east of the Black Hills. The advective heat-flow system is caused by a hydraulic gradient that slopes downward to the east and causes upward groundwater flow in the discharge areas in south central South Dakota and north central Nebraska [Gosnold, 1988]. Two modes of heat advection are suggested to occur. Advection due to cross-formational flow through fractures toward the surface is suggested by the work of Bredehoeft et al. [1983]. This mode of advection could be particularly significant near gaining streams and other discharge areas. Advection due to confined groundwater flow within the Dakota, Minnelusa and Madison aquifers underlying the region is suggested by several hydrologic studies of [Schoon, 1971; Schoon and McGregor, 1974; Downey, 1986]. Heat advection due to updip groundwater flow occurs over the anomalous area and could account for most of the thermal anomaly.

Fracture leakage

The occurrence and magnitude of cross-formational flow from the Dakota aquifer through fractures in the overlying confining layers was deduced during an extensive study by J.D. Bredehoeft and colleagues and is summarized by Bredehoeft et al. [1983]. Vertical flow velocities computed by Bredehoeft et al [1983] range as high as 3 X 10^{-11} m s^{-1} (Fig. 2). Much of the region of upflow coincides with the heat flow anomaly except for the area west of the Keya Paha river on both sides of the South Dakota-Nebraska border.

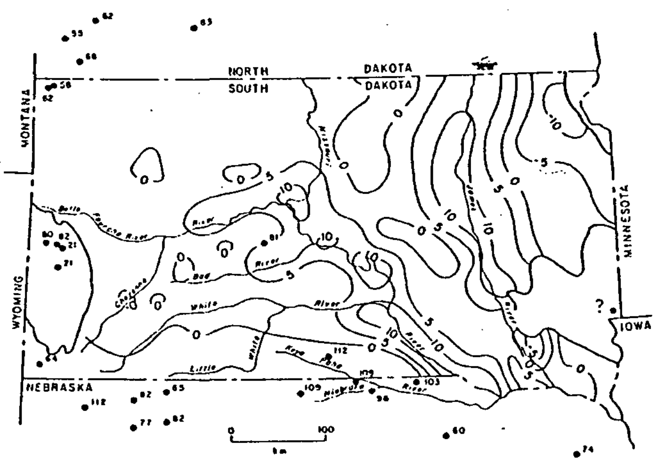

Figure 2. Contours of upward fracture-leakage velocity in 10^{-11} ft s^{-1}. Heat flow data are included for comparison.

A relationship between heat flow, water velocity, and distance of flow for a vertical one-dimensional system [Lachenbruch and Sass, 1977] may be used to calculate advection based on Bredehoeft et al.'s [1983] flow velocities as follows:

$$\ln \frac{Q_2}{Q_1} = \frac{V D \quad C_p}{K} \qquad (1)$$

Q_1 is heat flow at the base of the zone of flow, Q_2 is heat flow at the top, V is Darcy velocity in m s^{-1}, D is the length of the zone in meters, is density of the fluid in Kg m^{-3}, C_p is heat capacity of the fluid in W s Kg^{-1}, and K is thermal conductivity in W m^{-1} K^{-1}.

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Applying Eq. 1 to a region within 10's of meters from the fracture predicts that vertical water flow velocities of the order of 10^{-9}-10^{-10} m s^{-1} could produce a surface heat flow anomaly of greater than 120 mW m^{-2} with a heat flow value of 60 mW m^{-2} below the advective zone and an effective thermal conductivity of 1.2 W m^{-1} K^{-1} for the Cretaceous shales [Gosnold, 1988]. However, these velocities are 1-2 orders of magnitude greater than the velocities computed for the vertical flow by Bredehoeft et al. [1983]. This result suggests that fracture leakage from the Dakota sandstone to the surface would account for only half the amplitude of the heat flow anomaly in central South Dakota.

An important aspect of the numerical models used to produce Figure 3 is that heat flow near the

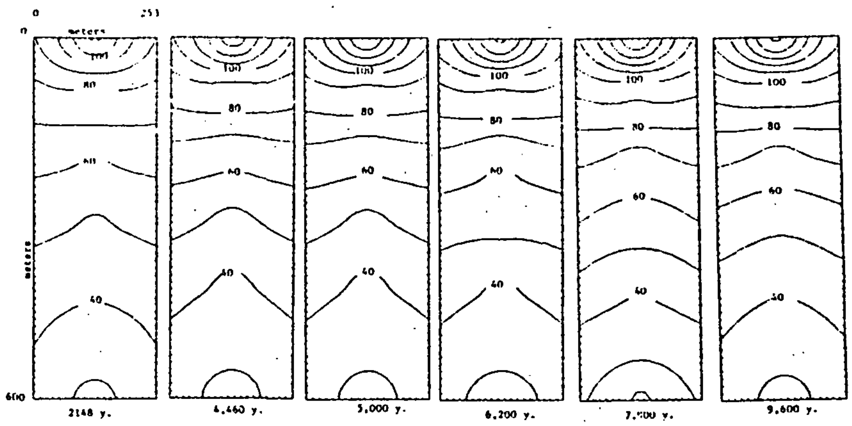

Figure 3. Heat flow contours around a 700 meter vertical crack at different times after the onset of vertical water flow at a velocity of 3×10^{-9} m s^{-1}. Heat flow is increased dramatically near the surface and is reduced near the water source at the bottom of the crack.

surface is increased but heat flow near the base of the fracture is reduced. This result is a necessary consequence of maintaining an energy balance in the groundwater flow system. No energy is actually introduced by the groundwater flow, it is simply redistributed. Predictions of the numerical models differ in this respect from those of the one-dimensional, steady-state condition predicted by Eq. 1.

Temperature gradient curves from heat flow measurements could provide a test for the fracture-leakage model. However, only one of the heat flow holes lies within the region of vertical flow identified by Bredehoeft et al [1983]. Eq. 1 and the numerical models predict that heat flow should vary as a function of the vertical length of groundwater flow. Thus, for constant conductivity and groundwater flow velocity, the magnitude of the heat flow anomaly should vary systematically in a drill hole. This variation would be apparent in the temperature - depth and gradient - depth plots with upward flow corresponding to a decreasing temperature gradient and is shown in theory in the plot labelled THEORETICAL in Figure 4.

Inspection of the temperature-depth and gradient-depth plots from heat flow sites (Figure 4) suggests that none of the sites lie in regions affected by fracture leakage. Generally, this interpretation agrees with the map of Bredehoeft et al. [1983]. The only exception is the site near Hayes in central South Dakota which lies on the 5 ft s^{-1} contour line but shows no effects of fracture leakage.

On the basis of the mapped extent of fracture leakage, it appears that upward leakage occurs primarily in and near stream valleys such as the Missouri, Cheyenne, White and James rivers. All but the James river valley, which lies in the flat bed of the James lobe of the Wisconsinan glaciation, are deeply incised and have locally steep hydraulic gradients. Thus, most of the heat advection due to variation would be apparent in the temperature-depth and gradient - depth plots with upward flow corresponding to a decreasing temperature gradient and is shown in theory in the plot labelled THEORETICAL in Figure 4. fracture leakage may be confined to the areas around the stream valleys.

Confined groundwater flow

The heat flow anomaly in north-central Nebraska and south-central South Dakota, where no cross-formational groundwater flow was computed by Bredehoeft et al. [1983], as well as about half of the heat flow anomaly in the fracture leakage zones could be caused by updip flow in as many as three regional aquifers. Water flow velocities of approximately 2×10^{-7} to 1.9×10^{-8} m s^{-1} were calculated for confined flow in the Madison and Dakota aquifers in the South Dakota by Downey [1986]. Water flow velocities for the Minnelusa aquifer, which is more than twice as thick as the Madison and Dakota aquifers in the study area and has transmissivity values equal to those of the Madison aquifer [Downey, 1986], were not included in Downey's [1986] study. However, the similarities in transmissivity, hydraulic gradient and recharge areas between the Minnelusa, Dakota and Madison aquifers suggest that flow velocities in the Minnelusa should be similar to those in the Madison and Dakota aquifers.

Heat advection by updip flow of groundwater within the Dakota, Minnelusa and Madison aquifers was computed using a finite difference model. The calculations show that velocities of the order of 6-7 $\times 10^{-8}$ m s^{-1} produce anomalous surface heat flow values of the order of 80 to 100 mW m^{-2}. These values would generate the observed regional anomaly, and would combine with advection due to fracture leakage to generate the localized, high values of 130 mW m^{-2}. The models for fracture-leakage and updip flow in the suggest that both modes of advection contribute to the heat flow anomaly.

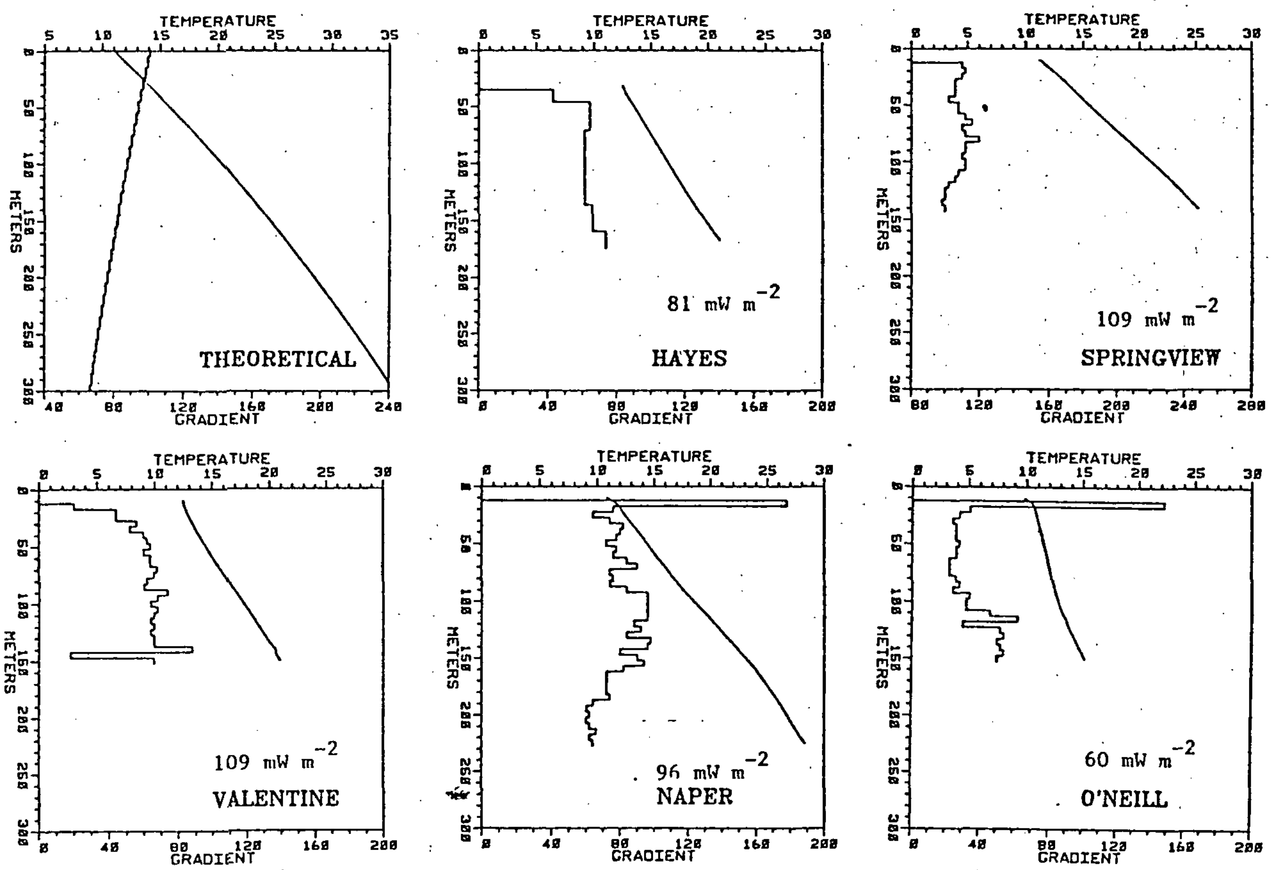

Figure 4. Temperature-depth and gradient-depth curves from northern Nebraska and central South Dakota. The plot labelled THEORETICAL is predicted from Eq. 1. and shows how the temperature gradient would decrease with depth in a region of homogeneous upward groundwater flow. The plot labelled Hayes is from Sass and Galanis [1983] and lies on the 5 x 10 $^{-11}$ ft s^{-1} contour line in Fig. 2. Locations of the holes can be matched to the heat flow values printed above the name.

Energy balance

An important aspect of the advection model is that the high heat flow due to upward water movement must be balanced by low heat flow due to downward water movement. Conceptually, low heat flow should occur in the recharge area in and around the Black Hills. The concept is empirically supported by heat flow values of about 20 mW m^{-2} (see Figure 1) reported for two localities in the Black Hills [Sass et al, 1971]. The anomalous heat flow component for these two low values is estimated to be about-70 mW m^{-2} by subtracting the low values from the high values.

Determination of the quantity of anomalous energy flux in the area would require tens-of-thousands of heat flow holes. However, a reasonable estimate can be calculated from the product of the average heat flow and the area of the anomaly. The positive anomaly of about 40 mW m^{-2} extends over an area of 40,000 km^2 quantity and is of the order of 1.6 GW. The negative anomaly of about -70 mW m^{-2} extends over the crystalline outcrops and aquifer outcrops around the eastern side of the Black Hills. A lesser negative anomaly of about -60 mW m^{-2} is computed for the descending limb of the of the groundwater flow systems in the Kennedy Basin. The recharge area for the aquifers is varies in character in that most of the recharge comes from streams that cross outcrops of the aquifers and lesser amounts of recharge come from precipitation [Downey, 1986]. The area of groundwater recharge in the crystalline rocks is also difficult to estimate. However, for recharge from the aquifer outcrops and from the crystalline rocks, a total recharge area of only about 8,600 km^2 and a negative heat flow component of 70 mW m^{-2} would generate an anomalous energy flux of about -0.6 GW. The area of down dip flow east of the Black Hills is calculated from the finite difference model to generate an anomalous heat flow of - 1.0 GW. Thus in general terms, the energy flux is balanced with about -1.6 GW in the recharge area and +1.6 GW in the anomalous area.

Conclusions

The heat flow anomaly is caused by advection of heat in upward flowing groundwater both by cross-formational flow through fractures and by updip flow in regional aquifers. Heat advection from flow in regional aquifers. Heat advection from updip flow occurs throughout the area, but cross-formational flow through fractures may occur only near gaining streams. The magnitude of anomalous heat flow due to fracture leakage reaches about 50 mW m^{-2} near gaining streams and the magnitude of anomalous heat flow due to updip flow is about 40 mW m^{-2} in most of the area. These values of anomalous heat flow cause surface heat flow values of the order of 100 - 130 mW^{-2}. The physical conditions that control regional groundwater flow system have existed for about 65 M.Y.

Acknowledgements

The field and laboratory work in this study were supported in part by Department of Energy grants DE-AS07-79ET27205 and DE-FG07-85ID12606, and NSF grant EAR-8417305. Equipment used in temperature gradient measurements, thermal conductivity measurements and other logistical support were provided by the Geothermal Laboratory at Southern Methodist University. D. Becker, L. Carter, D. Hanson, and J. Gibbens assisted in logging temperatures. D. Eversoll facilitated drilling and sample collecting in all holes in Nebraska. R. Baker of Burton, Nebraska generously allowed continued drilling and temperature logging at the one site that provided the initial incentive for this study.

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INFLOW PERFORMANCE RELATIONSHIPS FOR GEOPRESSURED GEOTHERMAL WELLS

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ABSTRACT

This paper presents methods and results of predicting geothermal well performance using actual flow test data taken from a typical geopressured geothermal well. DOW/DOE L.R. Sweezy No. 1 Well was used for the flow rate predictions. Using the method of either Jones (1976) or Fetkovich (1973), this study shows that the productivity index of geothermal wells changes not only with flow rate but also with time.

INTRODUCTION

Three reservoir factors, fluid temperature, production rate per well and size of the reservoir, are most important to the commercial development of geothermal resources. If the fluid temperature and production rate per well are given, then the gross power generation per well and the number of wells required for a desired power plant or heating process can be estimated.

The cost of development and operation of a geothermal resource is largely dependent on the number of wells to be drilled and operated. Therefore, an estimate of the productivity of a single well is necessary to determine whether the development and operation of a geothermal field is economically feasible. Thus, there is a need for accurate prediction of flow rates for geothermal wells.

In earlier studies conducted by Gudmundsson[1] and Ortiz[2], the productivity index (PI), was assumed to be constant not only with flow rate but also with time. The PI is the ratio of the production rate, to the pressure drawdown at the producing interval.

In oil well production practice, it is commonly assumed that the PI is constant for a wide range of flow rates which for most oil wells are less than 500 STB/day. However, the brine production of geothermal wells is generally 100 to 200 times greater than that of oil wells. A typical geopressured geothermal well in the Gulf Coast area can produce as much as 100,000 barrels per day of hot water at a well head pressure in excess of 2,000 psig for a considerable period of time.[3]

The PI of geothermal wells is not a constant primarily because of the effects of turbulence caused by high flow rates. Also, the depletion of reservoir pressure will cause the PI to decrease. Vogel[4] suggested that the inflow performance relationships (IPR) curve can be used to provide more accurate flow rate predictions than can be estimated with constant PI methods.

THEORY

This study presents two methods for predicting present and future production performance of geothermal wells. These methods will provide engineers the ability to predict geothermal flow rates with high accuracy.

Method A: Jones, Blount and Glaze Method

The Jones, et al.,[5] method has been successfully applied in both oil and gas flow rates prediction problems. The method can also be used for predicting production performance for geothermal wells because it considers turbulent flow effects on the well's productivity.

The Jones' method uses flow test data to determine a well's flow capacity. Data are required from either two or more stabilized flow tests or from two or more isochronal flow tests. In either case, flow rates and flowing bottomhole pressures must be either measured or calculated.

Jones, et al.,[5] suggested that flow rate and pressure drawdown can be related and written as:

$$p_r - p_{wf} = Cq + Dq^2 \qquad (1)$$

where: q = flow rate in STB/day
C = laminar flow coefficient
D = turbulence coefficient

From Eq. 1, it is apparent that a plot of $(p_r - p_{wf})/q$ vs. q has a slope of D, and an intercept of $C = \Delta p/q$, as q approaches zero.

Eq. 1 can be rearranged as:

$$PI = (C + Dq)^{-1} \qquad (2)$$

With values of C and D given, the PI value of the well can be calculated for any flow rates. Eq. 3 shows that the PI is a dependent of flow rate; as the flow rate increases, the PI decreases.

Method B: Fetkovich's Method

Fetkovich[6] suggested that gas wells and oil wells behave quite similarly and could be analyzed using the same flow equation:

$$q_o = Jo' \, (p_r^2 - p_{wf}^2)^n \qquad (3)$$

This equation will result in a straight line with a slope of 1/n on a plot of log q_o vs. log $(p_r^2 - p_{wf}^2)$. Eq. 3 considers the effects of high flow rate through the inclusion of exponent n. Generally, the value of n ranges from 0.568 to 1.0.

As indicated earlier, the PI also changes with time; as the reservoir pressure decreases the PI decreases. Fetkovich used the following equation for future flow rate calculations:

$$q_o = Jo_i' \left(\frac{p_r}{p_{ri}}\right) (p_r^2 - p_{wf}^2)^n \qquad (4)$$

where Jo_i' is the initial productivity index at conditions of initial reservoir pressure.

EXAMPLE

In this study, actual flow test data from DOW/DOE L.R. Sweezy No. 1 Well[7] was used to predict flow rates using both method A and B mentioned above. L.R. Sweezy No. 1 is a geopressured geothermal well located in Vermilion Parish, Louisiana. This well was completed with a 5-1/2 inch production tubing and a 7-5/8 inch casing. The producing intervals were perforated at 13,349-13,388 ft. and at 13,395-14,406 ft. A downhole temperature of 237°F was measured at a depth of 13,395 ft., and the initial reservoir pressure at 13,395 ft. was 11,410 psia.

In order to determine the production performance of the geopressure reservoir, this well was subjected to a series of short term flow tests. However, test data from the first two flow tests were not reliable enough for analysis. Flow test results from flow tests 3, 4, and 5 are given in Table 1.

TABLE 1. Flow Test Data on L.R. Sweezy No. 1 Well

Flow Test No.	Average Flow Rate (STB/day)	Pressure Drawdown (psi)
3	6,455	380
4	8,615	560
5	10,977	820

Method A: Jones, et al., method

Based on the flow test data listed in Table 1, well performance data are given in Table 2 and the results are plotted on Figure 1. It is interesting to note that the values of Δp/q plotted against q define a straight line.

TABLE 2.
Performance Data for L.R. Sweezy No. 1 Well

Flow Rate (STB/day)	Pressure Drawdown (psi)	Δp/q (psi/STB/day)	PI (STB/day/psi)
6,455	360	0.056	17.8
8,615	560	0.065	15.4
10,977	820	0.075	13.3

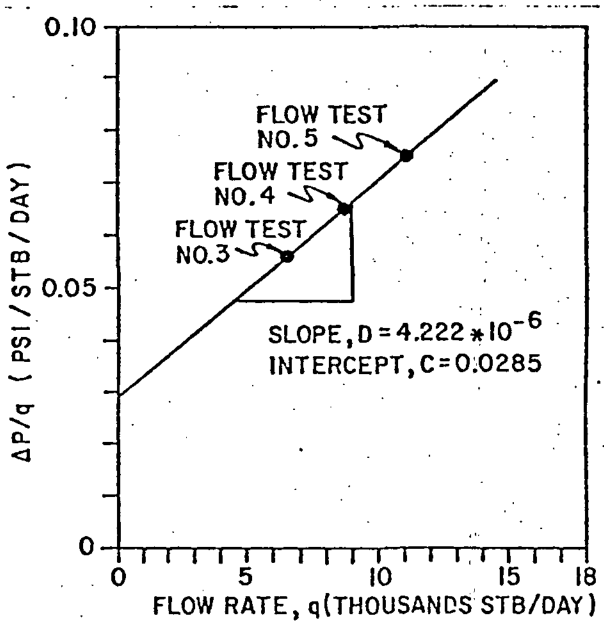

Fig. 1 : Analysis of flow test data for L.R.Sweezy No. 1 well.

In Figure 1, the slope of line, D is 4,222 * 10^{-6}, and the intercept, C is 0.0285. With C and D given, Jones' IPR curve is plotted in Figure 2.

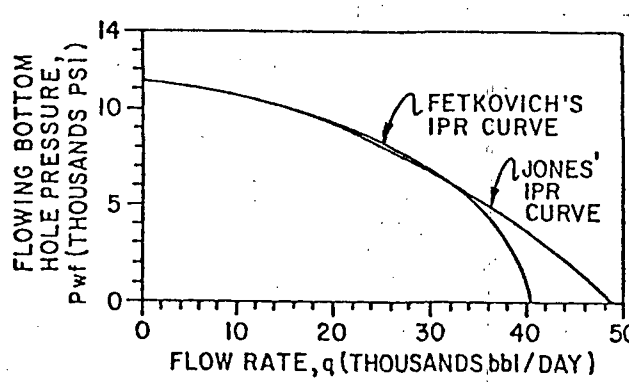

Fig. 2 : Inflow performance curve for L.R.Sweezy No. 1 well.

Method B: Fetkovich's Method

With the same flow test data given in Table 1, Figure 3 shows that log q_o vs. log $(p_r^2 - p_{wf}^2)$, plots as a straight line with a slope of 0.66 and a Jo value of 0.178 for an initial reservoir pressure of 11,410 psi.

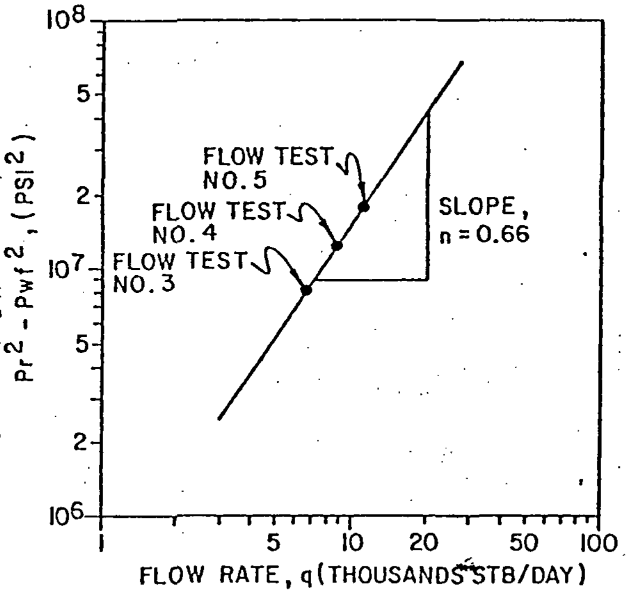

Fig.3: Flow test performance curve for L.R.Sweezy No.1 well.

Using Eq. 3, flow tests for various flowing bottomhole pressures can be calculated. For comparison, Fetkovich's IPR curves is also plotted in Figure 2. The PI values calculated by Jones' and Fetkovich's methods are listed in Table 3.

Eq. 4 was used for future flow rate predictions. Future IPR curves for reservoir pressure of 10,000 psi and 9,000 psi were then plotted in Figure 4. Also, future PI values for a fixed flow rate of 8,000 STB/day are given in Table 4.

TABLE 3.
PI Values Calculated by Jones' & Fetkovich's Methods

Flow Rate (STB/day)	PI value calculated by Jones' method (STB/day/psi)	PI value calculated by Fetkovich's method (STB/day/psi)
4,000	22.0	23.1
8,000	16.1	15.9
12,000	12.6	12.6
16,000	10.4	10.6
20,000	8.9	9.2
24,000	7.7	8.0
28,000	6.8	7.1
32,000	6.1	6.2

TABLE 4: Future PI Values for a Fixed Flow Rate of 8,000 STB/day

Reservoir Pressure (psi)	PI Values (STB/day/psi)
11,410 (current)	15.9
10,000	11.3
9,000	8.5
8,000	6.1
7,000	5.2

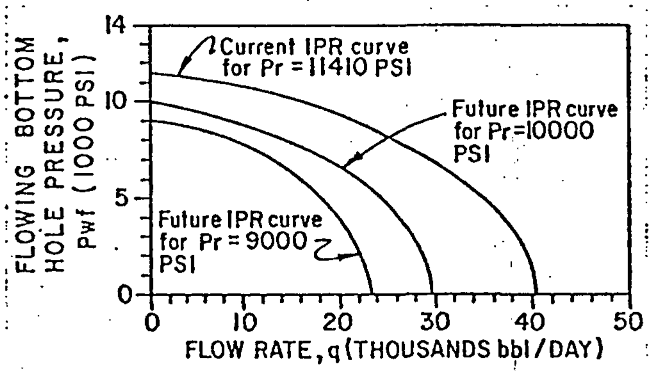

Fig.4: Current and future IPR curves for L.R.Sweezy No.1 well.

DISCUSSION

As shown in Figure 2, Jones' IPR curve is a concave downward curve, which results from high flow rate turbulence effects; the PI decreases as the flow rate increases. For example, at a flow rate of 12,000 STB/day, the PI would be 12.6 STB/day/psi, and the pressure drawdown would be 950 psi. However, if the flow rate increases to 24,000 STB/day, the PI decreases to 7.7 STB/day/psi and the pressure drawdown increases to 3,116 psi.

From Figure 2, it is interesting to note that Fetkovich's and Jones' methods produce very similar IPR curves. The PI value calculated by both methods are quite close to each other, as listed in Table 3. However, the maximum flow rate predicted by Jones' method was larger than that predicted by Fetkovich's method, because, Jones' method is primarily for calculations of one-phase flow, and Fetkovich's method can be used for two-phase flow calculations. Figure 4 shows that the shapes of both current and future IPR curves are similar. Table 4 indicates that the PI value for a fixed flow rate of 8,000 STB/day decreases with decreasing reservoir pressure. However, the nature of the change in the productivity index with reservoir pressure depletion requires further field study.

CONCLUSIONS

The major conclusions reached by this study are:

1. Jones' and Fetkovich's methods each provide more accurate geothermal well performance predictions than does the constant PI method.

2. The productivity index of geothermal wells decreases as flow rate increases. Also, a reduction in reservoir pressure will cause the PI to decrease.

3. Good flow test data are essential for accurate flow rate predictions.

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NORTH DAKOTA MINING AND MINERAL RESOURCES RESEARCH INSTITUTE

- COAL BY-PRODUCTS UTILIZATION LABORATORY
- FUELS ANALYSIS LABORATORY
- NATURAL MATERIALS ANALYTICAL LABORATORY

BOX 8103, UNIVERSITY STATION, GRAND FORKS, NORTH DAKOTA 58202 PHONE: (701) 777-3132

August 24, 1987

Mr. Howard Ross
University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way
Salt Lake City, Utah 84108

Dear Mr. Ross:

Please find enclosed one (1) copy of the final report entitled, "Geothermal Resource Assessment of South Dakota." This final report was prepared for the United States Department of Energy under Contract Number DE FG-07-85ID12606.

Should you have any questions or desire any additional copies, please contact me.

Sincerely,

W. D. Gosnold,

Dr. William D. Gosnold, Jr.
Principal Investigator

AMF

Enclosure

NORTH DAKOTA MINING AND MINERAL RESOURCES RESEARCH INSTITUTE

- COAL BY-PRODUCTS UTILIZATION LABORATORY
- FUELS ANALYSIS LABORATORY
- NATURAL MATERIALS ANALYTICAL LABORATORY

BOX 8103, UNIVERSITY STATION, GRAND FORKS, NORTH DAKOTA 58202 PHONE: (701) 777-3132

May 8, 1987

Ms. Peggy Brookshire
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Ms. Brookshire:

We request a no-cost extension of our DOE Contract No. DE-FG07-85ID12606 until July 1, 1987. Our initial plans were for assessment of geothermal resources contained in two aquifiers, the Dakota Sandstone and the Madison Limestone, in South Dakota. Our research during the winter and spring quarters has provided data that will allow us to include eleven water bearing formations. Seven of these formations are aquifiers with effective porosities greater than five percent and containing as much or more water than is contained in the Dakota Sandstone. The temperatures in these aquifiers range from about 40 degrees Centigrade to about 120 degrees Centigrade. Inclusion of these aquifiers in our resource assessment will increase the total amount of geothermal resources in South Dakota by as much as two to five times. This is why we are requesting an extension. We can devote full time to analysis of these aquifiers during May and June, and in our efforts will provide a far better analysis of the geothermal resources than we originally anticipated.

We still have operating funds in our budget and we request to restructure their expenditure to facilitate our continued analysis and completion of the final report. As per your phone call with Sherry, we will move $2,817 from Travel to Salaries. The budget is attached.

We have sent a copy of the first draft of our final report to Howard Ross at UURRI. This draft copy includes most of the technical information we have collected in this study with the exception of the resource analyses for the aquifiers. These analyses are in progress and should be completed some time in mid-May. If you would like a copy as it stands at this time, please let us know.

Please do not hesitate to contact me if any further information or explanation is necessary.

Sincerely,

W.D. Gosnold Jr.

William D. Gosnold, Jr.
Principal Investigator

Alex Kotch

Alex Kotch, Director
Office of Research and Program Development
WDG/clh
c: H. Ross

	Extension & Revsion 1/7/87	+ or -	Revised Balance 3/16/87	+ or -	Revision Request 5/7/87
Salaries and Benefits	-0-	+2400.00	2400.00	+2817.00	5217.00
Travel	6810.18	-2400.00	4410.18	-2817.00	1593.18
Supplies	616.00		616.00		616.00
Other	-0-		273.00		273.00
Indirect Costs	1564.42		1542.00		1542.00
TOTAL	9263.60		9263.60		9263.60

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Rec 7/3/87

Under the authority of Public Law 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*: Geothermal Research, Development, and Demonstration Act of 1977

1. PROJECT TITLE Geothermal Resource Assessment Research	2. INSTRUMENT TYPE [X] GRANT ☐ COOPERATIVE AGREEMENT
	4. INSTRUMENT NO. DE-FG07-85ID12606 — 5. AMENDMENT NO. M004
3. RECIPIENT *(Name, address, zip code, area code and telephone no.)* University of North Dakota, Mining & Mineral Resource Research Institute, P.O.Box 8103 University Station, Grand Forks, ND 58202	6. BUDGET PERIOD FROM: 12/30/86 THRU: 7/1/87 — 7. PROJECT PERIOD FROM: 8/9/85 THRU: 7/1/87
8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)* Dr. William D. Gosnold (701) 777-2631	10. TYPE OF AWARD ☐ NEW ☐ CONTINUATION ☐ RENEWAL [X] REVISION ☐ SUPPLEMENT
9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)* Susan Hoffman (701) 777-4141	12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)* R. Jeffrey Hoyles (208) 526-0790 U.S. Department of Energy Idaho Operations Office 785 DOE Place, Idaho Falls, ID 83402
11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)* Peggy Brookshier (208) 526-1403 U.S. DOE, Idaho Operations Office 785 DOE Place, Idaho Falls, ID 83402	

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T [X] INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number	15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION		b. CUMULATIVE DOE OBLIGATIONS	
(1) DOE Funds Obligated This Action	$ -0-	(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ -0-
(2) DOE Funds Authorized for Carry Over	$ 9,263.60		
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-	(2) Prior Budget Periods	$ 47,000
(4) DOE Share of Total Approved Budget	$ 9,263.60		
(5) Recipient Share of Total Approved Budget	$ -0-	(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 47,000
(6) Total Approved Budget	$ 47,000		

17. TOTAL ESTIMATED COST OF PROJECT $ ____
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ____ *(Date)* ____

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☐ C (Cooperative Agreements).

d. Application/proposal dated 2/4/87, ☐ as submitted [X] with changes as negotiated

19. REMARKS

This modification revises the budget categories with no increase in obligated funds. Revision attached.

20. EVIDENCE OF RECIPIENT ACCEPTANCE	21. AWARDED BY
____ *(Signature of Authorized Recipient Official)* *(Date)*	R. Jeffrey Hoyles 6/26/87 *(Signature)* *(Date)*
____ *(Name)*	R. Jeffrey Hoyles *(Name)*
____ *(Title)*	Contracting Officer *(Title)*

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA-459C
(10/80)

FORM APPROVED
OMB No. 1900-0127

1. Program/Project Identification No. DE-FG07-85ID12606	2. Program/Project Title Geothermal Resource Assessment Research
3. Name and Address University of North Dakota P.O.Box 8103 University Station, Grand Forks, ND 58202	4. Program/Project Start Date 8/9/85 5. Completion Date 7/1/87

SECTION A - BUDGET SUMMARY

Grant Program, Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non-Federal (f)	New or Revised Budget: Total (g)
1. 12606		$	$	$9,263.60	$	$9,263.60
2.						
3.						
4.						
5. TOTALS		$	$	$9,263.60	$	$9,263.60

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	Grant Program, Function or Activity: (1) 12606 (Carryover)	(2)	(3)	(4)	Total (5)
a. Personnel	$ 2,400.00	$	$	$	$ 5,217.00
b. Fringe Benefits	-0-				-0-
c. Travel	4,410.18				1,593.18
d. Equipment	-0-				-0-
e. Supplies	616.00				616.00
f. Contractual	-0-				-0-
g. Construction	-0-				-0-
h. Other	273.00				273.00
i. Total Direct Charges	7,699.18				7,699.18
j. Indirect Charges	1,564.42				1,542.00
k. TOTALS	$ 9,263.60	$	$	$	$ 9,263.60
7. Program Income	$	$	$	$	$

(7-81)

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:

1. PROJECT TITLE
Geothermal Resource Assessment Research

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
University of North Dakota, Mining & Mineral Resource Research Institute, P.O. Box 8103, University Station, Grand Forks, ND 58202

4. INSTRUMENT NO. DE-FG07-85ID12606

5. AMENDMENT NO. Orig

6. BUDGET PERIOD FROM: 8/9/85 THRU: 8/9/86

7. PROJECT PERIOD FROM: 8/9/85 THRU: 8/9/86

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
Dr. William D. Gosnold (701)777-2631

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Sue Hoffman (701)777-4151

10. TYPE OF AWARD
☒ NEW ☐ CONTINUATION ☐ RENEWAL
☐ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Peggy A. Brookshier (208)526-1403
U.S.DOE, Idaho Operations Office
550 Second Street, Idaho Falls, ID 83401

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Ronald A. King (208)526-1912
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☒ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
89X0224.91	AM1510000	ID-54-91/4/0	

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ 47,000
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-
(4) DOE Share of Total Approved Budget	$ 47,000
(5) Recipient Share of Total Approved Budget	$ -0-
(6) Total Approved Budget	$ 47,000

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 47,000
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 47,000

17. TOTAL ESTIMATED COST OF PROJECT $ ____________

(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ____________ *(Date)* ____________

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☐ C (Cooperative Agreements).

d. Application/proposal dated Undated, ☐ as submitted ☒ with changes as negotiated

19. REMARKS
This Grant consists of this NFAA, Part I-Budget Plan, Part II Conditions, Part III-Statement of Work, and Part IV-Special Terms and Conditions. The DOE Financial Assistance Rules (10 CFR Part 600), OMB Circular A-110, and OMB Circular A-21, are incorporated by reference and attached hereto.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Alex Kotch 8/21/85
(Signature of Authorized Recipient Official) *(Date)*

Alex Kotch
(Name)

DIRECTOR - OFFICE OF RESEARCH AND PROGRAM DEVELOPMENT
(Title)

21. AWARDED BY

William C. Drake 8/9/85
(Signature) *(Date)*

William C. Drake
(Name)

Contracting Officer
(Title)

Grantee: University of North Dakota, North Dakota Mining and Mineral Resource Research Institute

BUDGET PLAN

1.	Salaries (Incl. Benefits)	$22,837.00
2.	Travel	13,000.00
3.	Supplies	400.00
4.	Other Services and Communications	500.00
	SUBTOTAL DIRECT	$36,737.00
5.	Indirect Costs	10,263.00
	TOTAL	$47,000.00

STATEMENT OF WORK

The Grantee shall conduct a summary assessment of low and moderate temperature geothermal resources in South Dakota.

The tasks to be conducted in the geothermal resource assessment of South Dakota are:

TASK 1 - Obtain a network of heat flow data in South Dakota. Specific elements of this task are:

a. Measure geothermal gradients in all available wells and drill holes, and

b. Determine thermal conductivities of the formations in the measured wells.

TASK 2 - Obtain sufficient stratigraphic data to produce structure contour maps of all significant lithologic units within the study area. Significant lithologic units are those having properties and/or stratigraphic position which may influence the temperature of a geothermal aquifer.

TASK 3 - Measure temperature gradients in deep wells that penetrate the geothermal aquifers, to calibrate the heat flow and thermal conductivity grids used in downward projection of temperature fields.

TASK 4 - Synthesize previously published data to produce temperature contour maps on the geothermal aquifers, i.e., Dakota (Cretaceous), Madison (Mississippian), Duperow (Devonian), and Red River (Ordovician).

TASK 5 - Prepare geothermal resource map of South Dakota using the format similar to other maps produced under the State Coupled Program (but at a scale of 1:1,000,000). Submit a draft copy of the map to DOE and appropriate DOE-designated reviewers prior to publication.

TASK 6 - Prepare a text that will accompany the geothermal resource map, which will be written in a style that may be readily understood by non-geologists. The text will include a description of geothermal resources in South Dakota, temperature contour maps for each geothermal aquifer, appropriate definitions, discussions of possible geothermal applications, and a list of current geothermal applications in South Dakota.

TASK 7 - The Final Report to the Department of Energy will include the geothermal resource map, the accompanying text, and a report describing the research project, methodology, and data gathered.

TASK 8 - Provide overall project management and complete and report on tasks in a timely manner. Management reports shall be provided as defined by the attached DOE Form EIA-459A - Reporting Requirements Checklist. The required reports are also summarized as follows:

1. Form DOE-538 Notice of Energy RD&D	30 days after award of grant
2. Quarterly Management Summary Report	15 days after calendar quarter end
3. Project Status ~~Project~~	15 days after calendar quarter end
4. Final Report (Draft)	Due 45 days prior to updated completion date
5. Final Report	Due on updated completion date
6. Financial Status Report - OMB Form 269	Due annually and upon completion

The deliverables resulting from the tasks outlined above which will be delivered to DOE are summarized as follows:

1. The Final Report--one camera-ready copy plus twelve additional copies--will be distributed as specified in the attached DOE Form EIA-459A.

2. Reports previously described under Task 8 above will be prepared and issued in the amounts and at the frequency shown.

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE REPORTING CHECKLIST

FORM EIA 459A
(10/80)

FORM APPROVED
OMB NO. 1900 0127

1. Identification Number: DE-FG07-85ID125606

2. Program/Project Title: Geothermal Resource Assessment

3. Recipient: University of North Dakota, Mining & Mineral Resource Research Institute

4. Reporting Requirements:

	Frequency	No. of Copies	Addressees
PROGRAM/PROJECT MANAGEMENT REPORTING			
[ ] Federal Assistance Milestone Plan			
[ ] Federal Assistance Budget Information Form			
[X] Federal Assistance Management Summary Report	Q	1,2,1,1,1	A,B,C,D,E
[X] Federal Assistance Program/Project Status Report	Q	1,2,1,1	A,B,D,E
[X] Financial Status Report, OMB Form 269	Y,F	1	A
TECHNICAL INFORMATION REPORTING			
[X] Notice of Energy RD&D	Y	1,1	A,F
[ ] Technical Progress Report			
[ ] Topical Report			
[X] Final Technical Report	F*	1,8**,2,1	A,B,D,E

FREQUENCY CODES AND DUE DATES:

A - As Necessary; within 5 calendar days after events.
F - Final; Upon completion date
Q - Quarterly; within 15 days after end of calendar quarter or portion thereof.
O - One time after project starts; within 30 days after award.
X - Required with proposals or with the application or with significant planning changes.
Y - Yearly; 30 days after the end of program year. (Financial Status Reports 90 days).
S - Semiannually; within 30 days after end of program fiscal half year.

5. Special Instructions:

*Draft Report due 45 days prior to completion date to allow for DOE review and comments and is within the Grant budget period.

**Camera ready copy must be included.

6. Prepared by: (Signature and Date) [signature] 7/2/85

7. Reviewed by: (Signature and Date)

REPORT DISTRIBUTION LIST

A. Elizabeth M. Hyster
Contracts Management Division

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

B. Peggy M. Brookshier
Advanced Technology Division

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

C. Earl G. Jones
Financial Management Division

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

D. Marshall Reed

U. S. Department of Energy
Forrestal Bldg., MS: CE-324
1000 Independence Avenue, S.W.
Washington, D. C. 20585

E. Duncan Foley

University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108

F. U. S. Department of Energy
Technical Information Center
P. O. Box 62
Oak Ridge, TN 37830

SPECIAL TERMS AND CONDITIONS FOR RESEARCH GRANTS

The requirements of this attachment take precedence over all other requirements of this grant found in regulations, the general terms and conditions, DOE Orders, etc., except requirements of statutory law. Any apparent contradiction of statutory law stated herein should be presumed to be in error until grantee has sought and received clarification from the Contracting Officer, whose signature appears on the face page of this award.

PAYMENTS

Payments under this award will be made by reimbursement by treasury check.

Cognizant finance office:

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

ATTENTION: Ronald A. King
Contracts Management Division

In addition to the initial supply of forms made available with this award, appropriate payment forms and instructions will be provided by that office upon request.

Except for technical data contained in pages N/A of the recipient's application, dated N/A, which are asserted by the grantee as being proprietary data, it is agreed that as a condition of this award, and notwithstanding the provisions of any notice appearing on the application, the Government shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever the technical data not identified in the above blanks contained in the application upon which this award is based.

PATENTS AND TECHNICAL DATA GRANT CLAUSES

The following clauses specifically apply (10 CFR 600 is attached).

10 CFR 600.118(b)(1) - Patent Rights (Small Business Firm or Nonprofit Organization)

10 CFR 600.118(b)(3) - Rights in Technical Data (Short Form)

10 CFR 600.118(b)(6) - Notice and Assistance

10 CFR 600.118(c)(2) - Reporting of Royalties

10 CFR 600.118(b)(5) - Authorization and Consent

NORTH DAKOTA MINING AND MINERAL RESOURCES RESEARCH INSTITUTE

- COAL BY-PRODUCTS UTILIZATION LABORATORY
- FUELS ANALYSIS LABORATORY
- NATURAL MATERIALS ANALYTICAL LABORATORY

BOX 8103, UNIVERSITY STATION, GRAND FORKS, NORTH DAKOTA 58202 PHONE: (701) 777-3132

April 22, 1987

Ms. Peggy Brookshire
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Ms. Brookshire:

We request a no-cost extension of our DOE Contract No. DE-FG07-85ID12606 until July 1, 1987. Our initial plans were for assessment of geothermal resources contained in two aquifers, the Dakota Sandstone and the Madison Limestone, in South Dakota. Our research during the winter and spring quarters has provided data that will allow us to include eleven water bearing formations. Seven of these formations are aquifers with effective porosities greater than five percent and containing as much or more water than is contained in the Dakota Sandstone. The temperatures in these aquifers range from about 40 degrees Centigrade to about 120 degrees Centigrade. Inclusion of these aquifers in our resource assessment will increase the total amount of geothermal resources in South Dakota by as much as two to five times. This is why we are requesting an extension. We can devote full time to analysis of these aquifers during May and June, and our efforts will provide a far better analysis of the geothermal resources than we originally anticipated.

We still have operating funds in our budget and we request to restructure their expenditure to facilitate our continued analysis and completion of the final report. From Travel, we would like to transfer $6,365 to Salaries and Benefits and $1,000 to Supplies.

We have sent a copy of the first draft of our final report to Howard Ross at UURRI. This draft copy includes most of the technical information we have collected in this study with the exception of the resource analyses for the aquifers. These analyses are in progress and should be completed some time in mid-May. If you would like a copy as it stands at this time, please let us know.

Please do not hesitate to contact me if any further information or explanation is necessary.

Sincerely,

William D. Gosnold, Jr.
Principal Investigator

Alex Kotch, Director
Office of Research and Program Development
WDG/jep
c: H. Ross

NOTICE OF FINANCIAL ASSISTANCE AWARD
(See Instructions on Reverse)

3/18/87 WAK

Under the authority of Public Law 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Research, Development, and Demonstration Act of 1977

1. PROJECT TITLE
Geothermal Resource Assisment Research

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
University of North Dakota, Mining & Mineral Resource Research Institute, P.O. Box 8103 University Station, Grand Forks, ND 58202

4. INSTRUMENT NO. DE-FG07-85ID12606

5. AMENDMENT NO. M003

6. BUDGET PERIOD FROM: 12/30/86 THRU: 5/1/87

7. PROJECT PERIOD FROM: 8/9/85 THRU: 5/1/87

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
Dr. William D. Gosnold (701) 777-2631

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Susan Hoffman (701) 777-4141

10. TYPE OF AWARD
☐ NEW ☐ CONTINUATION ☐ RENEWAL
☒ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Peggy Brookshier (208) 526-1403
U.S. DOE, Idaho Operations Office
785 DOE Place, Idaho Falls, ID 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Ronald A. King (208) 526-0790
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☒ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ -0-
(2) DOE Funds Authorized for Carry Over	$ 9,263.60
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-
(4) DOE Share of Total Approved Budget	$ 9,263.60
(5) Recipient Share of Total Approved Budget	$ -0-
(6) Total Approved Budget	$ 47,000.00

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period [*Total of lines a.(1) and a.(3)*]	$ -0-
(2) Prior Budget Periods	$ 47,000
(3) Project Period to Date *(Total of lines b. (1) and b. (2))*	$ 47,000

17. TOTAL ESTIMATED COST OF PROJECT $

(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD AGREEMENT TERMS AND CONDITIONS

This award agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)
b. Applicable program regulations *(specify)* ________ *(Date)* ________
c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☐ C (Cooperative Agreements).
d. Application/proposal dated 2/4/87 ☐ as submitted ☒ with changes as negotiated

19. REMARKS This modification revises the budget categories with no increase in obligated funds. Revision attached.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

(Signature of Authorized Recipient Official) *(Date)*

(Name)

(Title)

21. AWARDED BY

William C. Drake 3/16/87
(Signature) *(Date)*

William C. Drake
(Name)

Contracting Officer
(Title)

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA 459C
(10/80)

FORM APPROVED
OMB No. 1900-0127

1. Program/Project Identification No. DE-FG07-85ID12606	2. Program/Project Title Geothermal Resource Assessment Research	
3. Name and Address University of North Dakota P.O. Box 8103 University Station, Grand Forks, ND 58202		4. Program/Project Start Date 8/9/85
		5. Completion Date 5/1/87

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non Federal (d)	Federal (e)	Non Federal (f)	Total (g)
1. 12606		$	$	$ 9,263.60	$	$ 9,263.60
2						
3						
4						
5. TOTALS		$	$	$ 9,263.60	$	$ 9,263.60

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	12606 Grant Program, Function or Activity				Total (5)
	(1) (Carryover)	(2)	(3)	(4)	
a. Personnel	$ 2,400.00	$	$	$	$ 2,400.00
b. Fringe Benefits	-0-				-0-
c. Travel	4,410.18				4,410.18
d. Equipment	-0-				-0-
e. Supplies	616.00				616.00
f. Contractual	-0-				-0-
g. Construction	-0-				-0-
h. Other	273.00				273.00
i. Total Direct Charges	7,699.18				7,699.18
j. Indirect Charges	1,564.42				1,564.42
k. TOTALS	$ 9,263.60	$	$	$	$ 9,263.60
7. Program Income	$	$	$	$	$

NORTH DAKOTA
Mining and Mineral Resources Research Institute
Box 8103, University Station
Grand Forks, North Dakota 58202
Phone: (701) 777-3132

February 4, 1986

Mr. Ronald A. King, Contract Specialist
R & D Contracts Branch
Contracts Management Division
Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

RE: DOE Contract DE-FG07-851D12606
(Our fund 4589 and 4590)

Dear Mr. King:

We have received Modification No. M002 to the above referenced contract. The modification allows a $9,263.60 carry-over through May 1, 1987. Part of this carry-over allows $6,810.18 for travel. We would like to utilize $2,400 of this travel money for a research assistant who would help in preparing the final report and the geothermal resource map of South Dakota.

If this budget transfer is approved, travel would be reduced to $4,410.18, and the personnel category would be increased to $2,400.

Please contact me if other information is required, or if you have any questions.

Sincerely,

W. D. Gosnold

William D. Gosnold
Principal Investigator

Alex Kotch

Alex Kotch, Director
Office of Research and
Program Development

WDG/rfp

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Howard Ross

01/12/87

Under the authority of Public Law 93-410 ____ and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Research, Development, and Demonstration Act of 19

1. PROJECT TITLE
Geothermal Resource Assessment Research

2. INSTRUMENT TYPE
XX GRANT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
University of North Dakota, Mining & Mineral Resource Research Institute, P.O. Box 8103
University Station, Grand Forks, ND 58202

4. INSTRUMENT NO. DE-FG07-85ID1260

5. NO. MOD2

6. BUDGET PERIOD FROM 12/30/86 THRU 5/1/87

7. PROJECT PERIOD FROM 8/9/85 THRU 5/1/87

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
Dr. William D. Gosnold (701) 777-2631

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Susan Hoffman (701) 777-4141

10. TYPE OF AWARD
☐ NEW ☐ CONTINUATION ☐ RENEWAL
XX REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Peggy Brookshier (208) 526-1403
U.S. DOE, Idaho Operations Office
785 DOE Place, Idaho Falls, ID 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Ronald A. King (208) 526-0790
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ INDIVIDUAL
☐ LOCAL GOV'T X INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION		b. CUMULATIVE DOE OBLIGATIONS	
(1) DOE Funds Obligated This Action	$ -0-	(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 9,263.60
(2) DOE Funds Authorized for Carry Over	$ 9,263.60		
(3) DOE Funds Previously Obligated in this Budget Period	$ 9,263.60	(2) Prior Budget Periods	$ 37,736.40
(4) DOE Share of Total Approved Budget	$ 9,263.60		
(5) Recipient Share of Total Approved Budget	$ -0-	(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 47,000.00
(6) Total Approved Budget	$ 47,000.00		

17. TOTAL ESTIMATED COST OF PROJECT $ ____
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD AGREEMENT TERMS AND CONDITIONS
This award agreement consists of this form plus the following:
a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreemen
b. Applicable program regulations *(specify)* ____
c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☐ C
d. Application/proposal dated 12/3/86 ☐ as submitted XX with changes a

Inv Σ1-4 = $35,781.01
Project Ttl = 47,000.00
$ 11,218.99

19. REMARKS
This modification revises the budget categories with no increase in funds. Revision attached.

$ 1,955.39

20. EVIDENCE OF RECIPIENT ACCEPTANCE

____ *(Signature of Authorized Recipient Official)* *(Date)*

____ *(Name)*

____ *(Title)*

21. AWARDED BY

William C. Drake 1/6/87
(Signature) *(Date)*

William C. Drake
(Name)

Contracting Officer
(Title)

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA 459C
(10 80)

FORM APPROVED
OMB No. 1900 0127

1 Program/Project Identification No. DE-FG07-85ID12606	2 Program/Project Title Geothermal Resource Assessment Research
3 Name and Address University of North Dakota P.O. Box 8103 University Station Grand Forks, ND 58202	4 Program/Project Start Date 8-9-85 5 Completion Date 5-1-87

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non Federal (f)	New or Revised Budget: Total (g)
1 12606		$	$	$ 9,263.60	$	$ 9,263.60
2						
3						
4						
5 TOTALS		$	$	$ 9,263.60	$	$ 9,263.60

SECTION B - BUDGET CATEGORIES

6 Object Class Categories	Grant Program, Function or Activity: (1) 12606 (Carryover)	(2)	(3)	(4)	Total (5)
a Personnel	$ -0-	$	$	$	$ -0-
b Fringe Benefits	-0-				-0-
c Travel	6,810.18				6,810.18
d Equipment	-0-				-0-
e Supplies	616.00				616.00
f Contractual	-0-				-0-
g Construction	-0-				-0-
h Other	273.00				273.00
i Total Direct Charges	7,699.18				7,699.18
j Indirect Charges	1,564.42				1,564.42
k TOTALS	$ 9,263.60	$	$	$	$ 9,263.60
7 Program Income	$	$	$	$	$

NORTH DAKOTA

Mining and Mineral Resources Research Institute
Box 8103, University Station
Grand Forks, North Dakota 58202
Phone: (701) 777-3132

December 3, 1986

Mr. Howard Ross
Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108

Dear Mr. Ross:

This is to advise you that we are requesting a no-cost time extension of the termination date of our DOE Contract No. DE-FG07-85ID12606, Geothermal Resource Assessment of South Dakota. The short time between the scheduled termination of our contract and the end of our field-data collection efforts is not adequate to prepare the final report and the geothermal resource map of South Dakota. I request that our termination date be extended until May 1, 1987. This date will allow us sufficient time to analyze the data and to prepare the map and final report.

In conjunction with the South Dakota project, I am also working with David Blackwell of Southern Methodist University on a DOE-funded project to produce a geothermal map of North America. My responsibilities for that map include the states of North Dakota, South Dakota, Nebraska, Montana, Wyoming, Colorado, Missouri, Iowa, and Minnesota. The participants in that project have been invited to present posters in a symposium on DNAG transects at the American Geophysical Union Meeting in San Francisco, December 7-12, 1986. Consequently, much of my current research effort is devoted to analyzing the South Dakota data for that poster session.

Please do not hesitate to contact me if any further information or explanation is necessary.

Sincerely,

William D. Gosnold
Principal Investigator

Alex Kotch, Director
Office of Research and Program
Development

WDG/amf

NORTH DAKOTA
Mining and Mineral Resources Researc
Box 8103, University Station
Grand Forks, North Dakota 58202
Phone: (701) 777-3132

Howard Ross

December 3, 1986

Mr. Ronald A. King, Contracts Specialist
R&D Contracts Branch
Contracts Management Division
Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, Idaho 83402

Dear Mr. King:

This is to advise you that we are requesting a no-cost time extension of the termination date of our DOE Contract No. DE-FG07-85ID12606, Geothermal Resource Assessment of South Dakota. The short time between the scheduled termination of our contract and the end of our field-data collection efforts is not adequate to prepare the final report and the geothermal resource map of South Dakota. I request that our termination date be extended until May 1, 1987. This date will allow us sufficient time to analyze the data and to prepare the map and final report.

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Please do not hesitate to contact me if any further information or explanation is necessary.

Sincerely,

W.D. Gosnold Jr.

William D. Gosnold
Principal Investigator

Alex Kotch

Alex Kotch, Director
Office of Research and Program Development

WDG/amf

NO $

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✓2	2786.34 ✓			39,163.96 ✓		1-31-86	ESL 3-31-86 ID Apr 2 86		
✓3	1538.13	9374.17 ✓		37,625.83 ✓		2-28-86	ESL 4-4 86		
✓4	26,406.84	35,781.01 ✓		11,218.99		9-30-86	ID 11/17/86	@ ESL	11/20/86
✓5	2,059.23	37,840.24		9,159.76 ✓		12-31-86	2/18/87	@ESL	2/23/87
✓6	1,124.86	38,965.10		8,034.90		3-31-87	5/4/87	@ESL	5/11/87
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GEOTHERMAL RESOURCES IN SOUTH DAKOTA

Submitted to:

Mr. Duncan Foley
URRI
Earth Science Laboratory
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Submitted by:

William D. Gosnold
Associate Professor
Department of Geology through the
North Dakota Mining and Mineral Resources Research Institute
Box 8103, University Station
University of North Dakota
Grand Forks, North Dakota 58202

Period: May 15, 1985 - May 15, 1986

Value: $48,715

W. D. Gosnold
William D. Gosnold
Principal Investigator

Alex Kotch
Alex Kotch, Director
Office of Research and Program Development

GEOTHERMAL RESOURCES IN SOUTH DAKOTA

Project Description

The objective of this project is to conduct a summary assessment of low and moderate temperature geothermal resources in South Dakota. The project will entail acquisition of heat flow, thermal conductivity, temperature gradient, and stratigraphic data. These data will be assimilated and evaluated using the method employed in the geothermal resource assessments of Nebraska (Gosnold and Eversoll, 1983) and North Dakota (Gosnold, 1984a). The resource assessment will be documented in two publications. First, a state map similar to those state maps prepared by NOAA for the U.S. Department of Energy in other DOE-State Coupled Programs will be prepared by the Mining and Mineral Resources Research Institute (MMRRI) at the University of North Dakota. Second, a written report describing the research project, data, methodology, and results will be prepared to accompany the map. The products of this project should be highly useful to geothermal developers. The map and report will contain information on which formations are useful geothermal aquifers, temperature contour maps of the aquifers, depths and thicknesses of the aquifers, compilation of published water chemistry data, and, where data exist, estimates of potential water production.

INTRODUCTION

Geothermal resource assessments for most of the states in the Great Plains province have been conducted as part of the U.S. Department of Energy State coupled Geothermal Resources Assessment Program. States included in the program are Colorado (Pearl, 1980), Kansas (Staveness and Steeples, 1982), Montana (Sonderegger and Bergatino, 1981), Nebraska (Gosnold and Eversoll, 1982), North Dakota (Harris et al., 1981; Gosnold, 1984), Oklahoma (Harrison et al., 1982), Texas (Woodruff and McBride, 1979), and Wyoming (Heasler, et. al., 1982). South Dakota is the lone remaining state in the Great Plains for which a summary geothermal resource assessment has not been conducted. This situation is somewhat ironic because South Dakota has been progressive in developing its geothermal resources and now has a number of active geothermal installations (see for example, Childs, 1984).

Previous studies of geothermal resources in South Dakota have: (a) dealt with general concepts (Schoon and McGregor, 1974), (b) been limited to a specific aquifer in a specific area of the state (Gries, 1977; Greeman and Meier, 1978), or (c) been site specific (Martinez; 1981). The South Dakota Geological Survey report on geothermal potentials in South Dakota by Schoon and McGregor (1974) has been the only publication to deal with the state as a whole.

Although School and McGregor's (1974) report treats geothermal resources only in general terms, it does contain a large amount of data and a geothermal gradient map of South Dakota. The data were compiled from several different sources, including previous publications, bottom-hole temperature data, drill stem tests, and temperature measurements of flowing wells. The geothermal gradient map compiled from the data shows a wide-spread occurrence of anomalously high geothermal gradients in central and south central South Dakota. Especially prominent is the region just west of the Missouri River in southern South Dakota where geothermal gradients are greater than 90°C km^{-1} (Figure 1).

Schoon and McGregor (1974) described geothermal systems in general terms only, and offered only speculative explanations for the source of the anomalously high geothermal gradients. The report also did not include any assessment of geothermal resources within the state.

Recent investigations (Gosnold, 1985) indicate that much of the anomalously high geothermal gradient area in central South Dakota, i.e., The Kennedy Basin, are causing by advective heat transfer in flowing aquifers.

At least two major aquifers in the Basin, the Madision limestone (Mississippian) and the Dakota (Cretaceous), recharge at outcrops in the Black Hills and discharge in ourcrops or subcrops to the east (Schoon, 1974; 1971; Back et al., 1983). The piezometric surface of the Dakota slopes from an elevation of about 1,000 metres at its outcrop in the Black Hills to about 500 metres at the Missouri River 360 km to the east (Schoon, 1974). There is a significant amount of easterly groundwater flow in this aquifer (Schoon, 1974). There is a significant amount of easterly groundwater flow in this aquifer (Schoon, 1971). Groundwater in the Madison aquifer flows easterly at rates as high as high as about 20 m/yr (Back et al., 1983). Schoon (1971) and Schoon and McGregor (1974) give evidence for a discharge from the Madison subcrop into the overlying Dakota in the eastern part of the Basin. Figure 2 is a cross section of the Kennedy Basin from the Black Hills to the Dakota outcrop east of the Missouri River, showing the piezometric surface for the Dakota and Madison formations, top of the

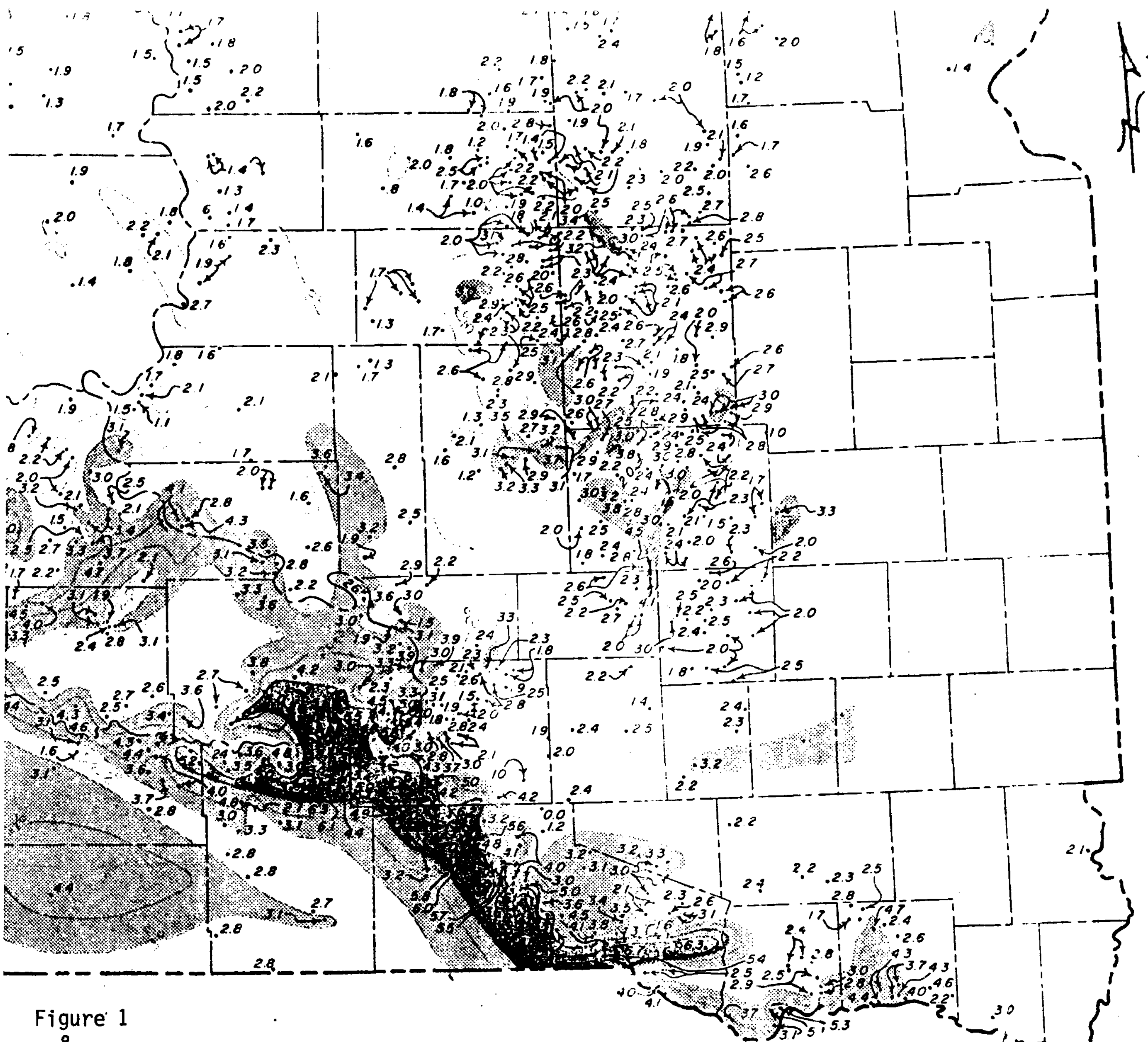


Figure 1

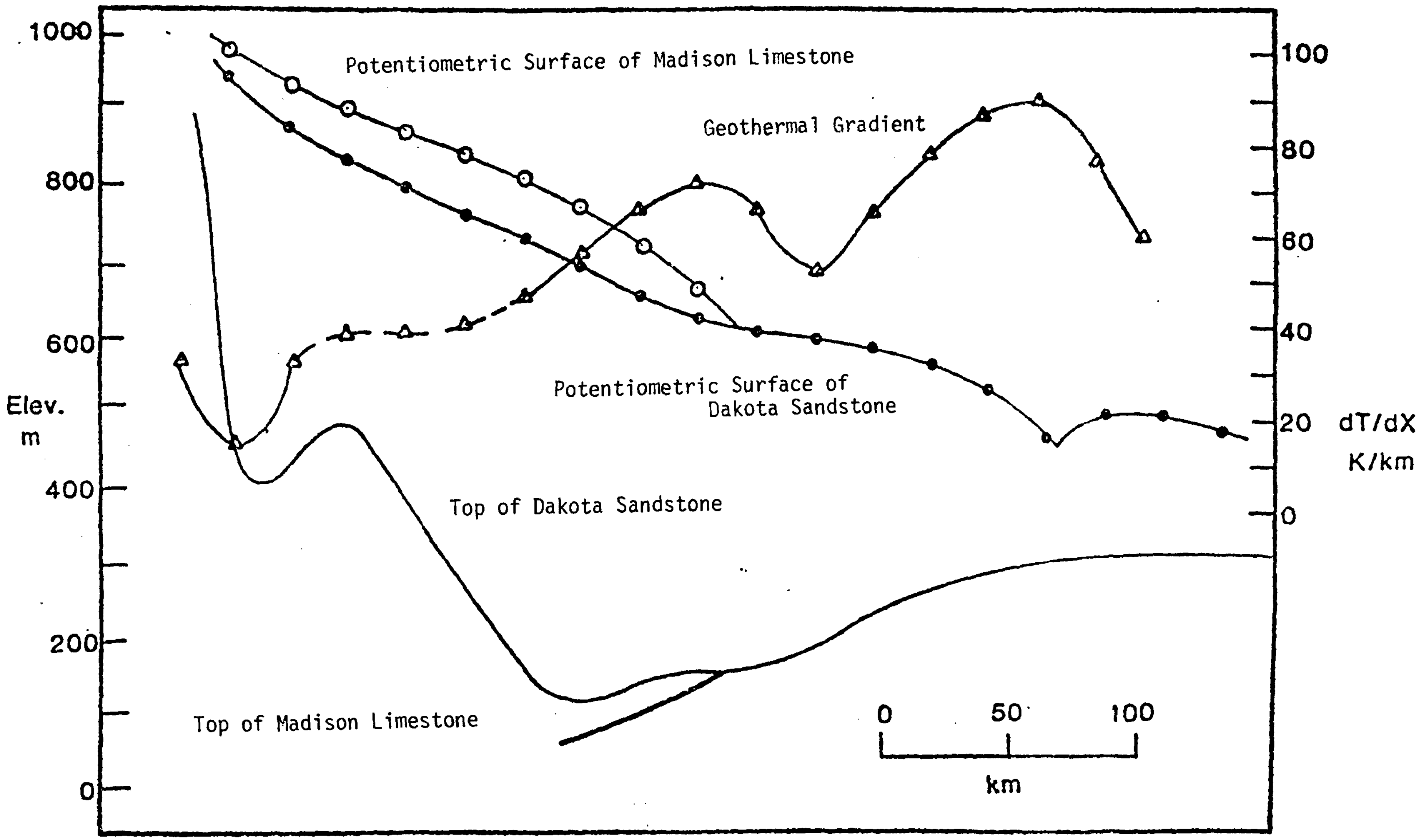
han 3° F. per 100 feet of depth.

rom 3° F. to 5° F. per 100 feet of depth.

of 5° F. per 100 feet of depth.

hermal gradient in °F per 100 feet of depth

10 0 10 20 30 40 50 miles


1000
800
600
400
200
0
Elev.
m
100
80
60
40
20
0
dT/dX
K/km
Potentiometric Surface of Madison Limestone
Geothermal Gradient
Potentiometric Surface of
Dakota Sandstone
Top of Dakota Sandstone
Top of Madison Limestone
0
50
100
km

Figure

Dakota, and the geothermal gradient. The geothermal gradient data, which were taken from Schoon and McGregor (1974), have a positive correlation with the structure of the Dakota and the subcrop contact between the Dakota and the Madison. These correlations appear to indicate a positive relationship between subsurface temperatures and groundwater flow through the Basin. The higher elevations for the potentiometric surface of the Madison reflect the higher elevation of the recharge area.

Recent studies by Neuzil et al., (1984) show that the Dakota is a semi-confined aquifer in which groundwater flows easterly and leaks upward into the overlying formations throughout the Basin. The upward leakage in the Kennedy Basin should cause a small advective heat flow component superimposed on the major flow system. These advective components probably account for the widespread occurrence of high temperature gradients in South Dakota reported by Schoon and McGregor (1974).

PROPOSED RESEARCH

The tasks to be conducted in the geothermal resource assessment are:

1. Obtaining a network of heat flow data within the study area. Specific elements of this task are:
   (a) Measure geothermal gradients in all available wells and drill holes.
   (b) Determine thermal conductivities of the formations in the measured wells.
2. Obtain sufficient stratigraphic data to produce structure contour maps of all significant lithologic units within the study area. Significant lithologic units are those having properties and or stratigraphic position which may influence the temperature of a geothermal aquifer.
3. Measure temperature gradients in deep wells that penetrate the geothermal aquifers. This phase of the project is necessary to calibrate the heat flow and thermal conductivity grids used in downward projection of temperature fields.
4. Data synthesis, including previously published data, i.e., Gries, 1977; Freeman and Meier, 1978; Martinez, 1981; Back et al., 1983; MacCary, 1984; Downey, 1984; Bredehoft et al., 1983; Konikow, 1976; Case, 1984; Iles, 1984; Kolm and Peter, 1984, Neuzil et al., 1984; Schoon, 1984, to produce temperature contour maps on the geothermal aquifers, i.e., Dakota (Cretaceous), Madison (Mississippian), Duperow (Devonian), and Red River (Ordovician).
5. Preparation of geothermal resource map using the format employed by NOAA in preparing other state geothermal resource maps.

6. Preparation of text that will accompany the geothermal resource map.

7. Final report to the Department of Energy.

Discussion of Research

TASK 1A: Temperature logging will be conducted during the 1985 field season. Two temperature logging systems will be available for use in this project. We presently have a new portable temperature logging system that can measure temperatures to within 0.001°C and can reach a depth of 1,143 metres. This logging system is capable of reaching the Dakota Sandstone throughout most of South Dakota. It will be used to measure all available wells that penetrate to the Dakota sandstone and all shallow wells that are available. We have a grant from the National Science Foundation (EAR-8417305, Michael Mayhew, personal communication) to outfit a logging truck with a computer-controlled, continuous temperature logging system. The continuous logging system will be capable of measuring temperatures with an accuracy of 0.01°C and of reaching depths of 2 km. This system will allow us to reach the Precambrian surface in most of South Dakota, except in the area of the Williston Basin. The continuous logging system will be installed in a logging truck owned by the North Dakota Geological Survey. Use of the truck for this project will be contributed by the North Dakota Geological Survey as part of the State of North Dakota's participation in the project.

The P.I. and the graduate student research assistants devote the entire field season, i.e., May 15 through August 15, to temperature logging operations. Two vehicles may be required at some times, and for that reason, the travel budget reflects anticipated costs for operating the second vehicle.

TASK 1B: The bedrock formations overlying the Dakota aquifer in South Dakota are upper Cretaceous marine sediments which include the Pierre Shale, Niobrara Fm, Carlile Shale, Greenhorn Limestone, Belle Fourche Shale, and Mowry Shale. Thermal conductivities of shales are notoriously difficult to measure in laboratory conditions and many previous measurements are unreliable (Blackwell et al., 1982, Sass and Galanis, 1983; Gosnold, 1984a). An inherent strength of the method of subsurface temperature analysis to be used in this study is that it uses the deep well temperature gradient and lithologic data as a virtual thermal conductivity estimator. The accuracy of such estimates has permitted prediction of subsurface temperatures to within 1°C at depths exceeding 2 km in the Williston and Denver Basins (Gosnold, 1984b). Consequently, the number of thermal conductivity measurements performed in the laboratory will be few and will include only carbonate rocks and coarse clastic rocks. The samples to be measured will be obtained on loan from the South Dakota Geological Survey in Vermillion, S.D.

TASK 2: Stratigraphic data on aquifers which may fit the requirements as geothermal aquifers is available in several publications, i.e., Downey (1984); McCarey (1984); Bredehoft et al., (1984), Schoon (1971); Neuzil et al., (1984). Additional stratigraphic data on other sedimentary formations is available in the form of well logs and other unpublished data from the South Dakota Geological Survey. We will compile a grid of representative stratigraphic sections from the available data. This grid of data will enable us to generate temperature contour maps for the geothermal aquifers using the HFS method. This task will require lengthy visits to the South Dakota Geological Survey at Vermillion and to the U.S. Geological Survey at Denver, Colorado. We are including these visits as part of the field travel expenses in the budget.

TASK 3: This task is essentially the same as Task 1a except that these data will be included on the geothermal resource map.

TASK 4: The data synthesis phase of the project will commence at the conclusion of the field season. Both research assistants and the P.I. will be active in this task for the duration of the project. The synthesis will include data on heat flow, temperature gradients, thermal conductivity, stratigraphy, water chemistry, formation porosity, water production, and other relevant material.

TASK 5: We have the capability to prepare a geothermal resource map in the format, i.e., color scheme and symbology, used by NOAA in preparing other state geothermal resource maps. However, size limitations in our equipment may require that the map scale be 1:1,000,000 instead of 1:500,000. The map will be prepared on a standard topographic base. The equipment usage will be contributed by the University of North Dakota as part of the State of North Dakota's participation in the project. If a map with a 1:500,000 scale is desired, we will have to let a subcontract and the budget would have to be expanded accordingly.

TASK 6: An explanatory text will be prepared to accompany the geothermal resource map. The text will be written in a style that may readily be understood by the potential geothermal developer who is not a professional geologist. The text will be thorough yet succinct. The text will include: a description of the geothermal resources within the state of South Dakota, a set of temperature contour maps for each geothermal aquifer, definitions of appropriate geological terms, discussions of possible geothermal applications, and a list of current geothermal applications in South Dakota.

TASK 7: The final report to the Department of Energy will include the geothermal resource map, the accompanying text, and a report describing the research project, methodology, and data gathered.

METHODOLOGY

The method of resource assessment will be a synthesis of heat flow data with thermal conductivity, temperature gradient, and stratigraphic data. This method, hence referred to as HFS for Heat Flow Synthesis, will enable us to construct accurate temperature contour maps for the geothermal aquifers underlying South Dakota. The HFS method has been used previously in Nebraska (Gosnold and Eversoll, 1983) and North Dakota (Gosnold, 1984a). In those Department of Energy supported research projects, the HFS method was found to provide subsurface temperature projections that are within 2°C of actual temperatures at depths greater than 2 km. In comparison with other geothermal resource assessment methods (Gosnold, 1984b), the HFS method was found to significantly improve the reliability of geothermal resource assessment. A thorough discussion of this method is given by Gosnold (1984a, pp. 5-8).

PROJECT DURATION

The proposed duration for the project is one year, commencing on May 15, 1985, and terminating on May 15, 1986. This will be the third state geothermal resource assessment conducted by the P.I., and the experience gained in geothermal resource assessments of Nebraska (Gosnold and Eversoll, 1983) and North Dakota (Gosnold, 1984) is a significant factor in determining the scope and duration of this project. It is expected that the proposed project will be completed within one year, but it is suggested that contingency plans for additional field work should be considered.

BUDGET NARRATIVE

Salary for the Principal Investigator is for 3.0 months during the summer field season. The P.I. and research assistants will spend a minimum of 60 days of each field season working in the field, locating and logging wells. Salaries for research assistants are for one quarter-time graduate research assistantships for the 12 months included in the project. Field expenses are computed for 7000 miles of travel during the summer and per diem for three persons working full time for 60 days.

BUDGET

I.	Salaries*			
	a. Will Gosnold, P.I. ($2,778/month)			
	1.5 months @ $3,056/month	$4,584		
	1.5 months @ $3,209/month	4,814		
			$ 9,398	
	b. Clerical/Drafting ($985/month)			
	.25 months @ $1,085	271		
	1.5 months @ $1,138	1,707		
			1,978	
	c. (2) Time Graduate Research Assistant ($339)			
	12 months each @ $339/month		8,136	
	Total Salaries		$19,512	
II.	Benefits @ 24% (of Ia and Ib)		2,730	
	Total Salaries and Benefits		$22,242	
III.	Travel			
	a. fieldwork	12,000		
	b. professional meetings (3 persons)	3,000		-cut to 1 person, 1 mtg.?
	Total Travel		$15,000	
IV.	Supplies		400	
V.	Communication		500	
VI.	Total Direct		$38,142	
VIa.	Indirect costs on campus @ 35% ($16,613)	5,815		
VIb.	Indirect costs off campus @ 22.1% ($21,530)	4,758		
			10,573	
	Total		$48,715	$47,000

* In budgeting salaries, we assumed a salary increase of 10 percent in January, 1985, and an additional 5 percent increment of July, 1985.

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THE
UNIVERSITY
OF
NORTH
DAKOTA

GEOLOGY DEPARTMENT
Box 8068, University Station
Grand Forks, North Dakota 58202
(701) 777-2811

10 October, 1984

Duncan Foley
Earth Science Laboratory
University of Utah Research Institute
420 Chipeta Way
Salt Lake City, UT

Dear Duncan:

Enclosed is a copy of a pre-proposal that I sent to Marshall Reed and Eldon Bray in September. Marshall and I discussed the proposal by telephone on Oct. 9, and he made several suggestions. First, he asked that I send a copy to you so that he can use your experience in this type of geothermal work. He also suggested that we design the project to last three years, and that there may be areas in addition to the Denver Basin that could be included in the study. Marshall was encouraging about funding the proposal and this appears to be good news for all concerned.

I understand that this project may be dovetailed with a proposal by Dave Blackwell to produce a heat flow map of North America. I do not know exactly what Dave has proposed, but I am somewhat familiar with his proposed project. I think it is a good idea.

Increasing the scope of the proposal to include other areas seems like a very good idea. In fact, having additional areas to explore could cut down on dead time in the field and make the overall operation more efficient. If we were operating in two or three other areas, at least one additional field assistant would be required. However, in the long run we would be getting those areas evaluated for the cost of an additional field assistant rather than for the cost of a new project. I've had only a few hours to consider other areas, and I would like to ask you for suggestions. At first glance, I suggest the San Luis Basin in Colorado, and the Williston Basin in eastern Montana. There should be no problem in working in both the Denver and San Luis Basins i.e., the logging truck could move easily between them. Eastern Montana is close to us; and, in a cooperative project with Blackwell, working there should not violate anyone's territorial sensitivities.

If the project is designed to include other areas, I would restructure the budget to include a three month summer effort by me rather than just two months. Also, we need to identify which particular tasks will be in conjunction with Blackwell's project, e.g., data compilation. Obviously there are a number of details to be worked out, and I look forward to receiving your suggestions before we prepare the final proposal.

Sincerely yours,

W.D. Gosnold, Jr.

William D. Gosnold, Jr.
Associate Professor

GEOTHERMAL RESOURCES IN THE DENVER BASIN

OBJECTIVES

The objective of this project is to provide an accurate assessment of low and moderate temperature geothermal resources in the Denver Basin. The methodology to be used is a synthesis of heat flow data with additional thermal conductivity, temperature gradient, and stratigraphic data. This method, hence referred to as HFS, has been used to provide subsurface temperature projections that are within 1 deg. C. of actual temperatures at depths greater than 2 kilometres (Gosnold and Eversoll, 1982; Gosnold, 1984). Consequently, the HFS method significantly improves the reliability of geothermal resource assessments over previous methods.

The current assessment of geothermal resources in the Denver Basin in Colorado (Sorey et. al., 1983) was based on linear temperature gradients derived from bottom hole temperature (BHT) data. Comparisons between BHT and HFS based resource assessments show that the BHT method may underestimate the geothermal resource by as much as 70% (Gosnold, 1984). Because the studies used for these comparisons, i.e., Nebraska and North Dakota, dealt with stratigraphic units similar to those in the Denver Basin, it is quite probable that the BHT based geothermal resource assessment for the Denver Basin is also quite low. Preliminary calculations based on available data suggest that the temperatures in the Dakota sandstone beneath Denver, Colorado may have been underestimated by 45 to 60 degrees Celsius.

IMPACT OF THIS PROJECT

A new resource assessment based on the HFS method could lead to interest in and development of a large resource in the high population-density areas east of the Colorado Front Range. Because this area was excluded from the Colorado geothermal resource assessment (Pearl, 1980), the possible existance of a geothermal resource in the plains area is virtually a secret shared by a few scientists. Some demographic characteristics of the Front Range area are that it is progressive, growing, and environmentally sensitive. Consequently, a well-managed publicity program on the magnitude and accessibility of this geothermal resource after the study is completed might significantly boost geothermal development in this and other areas.

PROPOSED RESEARCH

The essential elements in conducting the HFS method are:

1. Obtaining a network of heat flow data within the study area.

The number of heat flow sites necessary to complete the project is somewhat arbitrary. We propose to establish about ten heat flow sites within the Denver Basin. The procedure we propose to use is to piggyback on other drilling projects, e.g., petroleum exploration. We propose to obtain permission to take over dry holes that are drilled during our study and to complete those wells as heat flow sites. The completion will require filling the well with bentonite drilling mud and insertion of a small diameter casing.

2. Obtaining sufficient stratigraphic data to produce structure contour maps of all significant lithologic units within the study area.

A survey of current literature indicates that sufficient stratigraphic data can be obtained from published literature and from the Colorado Geologic Survey, and the U.S. Geologic survey.

3. Measuring temperature gradients in deep wells that penetrate formations of known thermal conductivity.

Deep equilibrium temperature gradient logs will be made on all available wells in the basin. We actually need only a few deep well logs to calibrate our calculations, however we intend to obtain as much equilibrium temperature data as possible during the course of the project.

The proposed duration for the project is 2 years commencing in January, 1985 and terminating in December 1986.

of the North Dakota Geological Survey's logging trucks. This system accounts for the equipment part of the budget. The consultant's fee is for 20 working days on campus at $100/day. The consultant's travel expenses are for 30 days per diem at $50/day and for air fare between Grand Forks and Los Angeles.

Field expenses are computed for 7000 miles of travel during each summer and for two persons working full time for 60 days each summer. The first field season will begin May 15, 1985.

The equipment budget is explained in the section on equipment. Construction of equipment will commence on January 15, 1985.

REFERENCES

Gosnold, W.D. and D.A. Eversoll, 1982, Geothermal Resources of Nebraska, 1:500,000 scale map, National Geophysical and Solar Terrestrial Data Center, N.O.O.A., Boulder, CO.

Gosnold, W.D., 1984, Geothermal resources in the Williston Basin: North Dakota, Geothermal Resources Council Transactions, v. 8, pp. 431-436.

Pearl, R.H., 1980, Geothermal resources of Colorado, 1:500,000 scale map, Colorado Geological Survey Map Series 14.

Sorey, M.L., M.J. Reed, D. Foley, and J. Renner, 1983, Low temperature geothermal resources in the central and eastern United States. <u>in</u> Assessment of low temperature geothermal resources of the United States - 1982, M.J. Reed, editor, U.S. Geological Survey Circular 892, pp. 51-66.

does T gear need to be bought (?) for deep logging, use DDB's?

PROPOSED BUDGET

5 notes

		198~~6~~ 5	198~~7~~ 6	TOTAL
(I)	Salaries:			
	a. P.I. (2 mo. summer)	$ 5,555	$ 6,110	$11,665
	b. (2) 1/4-time R. A.	9,000	9,900	18,900
	c. Field Asst. (3 mos)	2,250	2,475	4,725
(II)	Fringe benefits (24% of Ia)	1,333	1,466	2,800
(III)	Consultant fee	2,000		2,000
(IV)	Travel			
	a. Field work	10,000	10,000	20,000
	b. Prof. Mtgs. (2 pers.)	2,500	2,500	5,000
	c. Consultant	3,000		3,000
(V)	Supplies	200	200	400
(VI)	Communication	500	500	1,000
(VII)	Indirect Costs On Campus (35% of Ib, III, IVb, IVc, V, VI)	6,020	4,585	10,605
(VIII)	Indirect Costs Off Campus (22.1% of Ia, Ic, II, IVa)	4,671	4,431	8,660
(IX)	Total Ind. Costs:	10,691	9,016	19,265
(X)	Permanent Equip: Temperature logger	6,500		6,500
(XI)	Heat Flow Well Completion			
	Drill Rig Time ($100/hr)	4,000	4,000	8,000
	Casing (1-1/4in.)	6,250	6,250	12,500
(XI)	Total Budget:	63,337	52,417	115,755
	f →	63,779	ok	116,196

Salary for the Principal Investigator is for 2.0 months in each summer of the project. The P.I. will spend about 60 days of each field season working in the field, locating and logging wells. Salaries for research assistants are for one quarter-time graduate research assistantships for the academic months included in the study and for one field assistant during the summers. The research assistantships will commence on January 1, 1985.

The consultant will be R.E. Spafford. His role will be to design and install a continuous temperature logging system in one