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BURNS AND ROE ENTERPRISES, INC.

PRELIMINARY REPORT for DELIVERY ORDER No. 25

Subtask I: Assessment of Zugdidi Geothermal District Heating System

Subtask II: Financial Analysis

GEORGIA

March 1997

Prepared by:	**ArCi Consulting**
Submitted to:	**U.S. Agency for International Development**
Contract No.:	**CCN-0002-Q-00-3154-00** **Energy Efficiency and Market Reform Project** **Delivery Order No. 25,** **Subtask I:** Assessment of Zugdidi Geothermal District Heating System **Subtask II:** Financial Analysis

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Burns and Roe Enterprises, Inc.
1400 K Street N.W., Suite 1050, Washington, DC 20005
(202) 408-6831 Fax (202) 408-6835

March 18, 1997

Mr. Iqbal M. Chaudhry
U. S. Agency for International Development
320 21st Street N.W., Rm 4440 NS
Washington, DC 20523

Subject: Contract CCN-0002-Q-00-3154-00
Delivery Order No. 25 - Georgia
Zugdidi Geothermal District Heating System
EBRD Reconstruction Proposal - Preliminary Draft Report

Dear Mr. Chaudhry:

The Government of the Republic of Georgia has requested that the EBRD assist in preparing a district heating project for Zugdidi to utilize geothermal energy. USAID has agreed to fund a preloan project assessment and provide the services of Burns and Roe Enterprises to undertake the tasks specified in Delivery Order No. 25.

Attached is a copy of the preliminary report on the Zugdidi Geothermal Assessment prepared in Tbilisi by ARCI Consulting under the direction of Burns and Roe Enterprises, Inc. This report covers about 60% of the ARCI work required for preparation of the EBRD Pre-Loan Assessment.

The work remaining for completion of the Delivery Order includes, but is not limited to, the following:

1. Limited testing of the resource/wells (May 1997)

2. Privatization and Ownership Proposal

   a. Development of a program of institutional reforms for the Government of Georgia to privatize the geothermal production and district heating systems by means of a joint stock company.
   b. Recommendations on a company ownership structure, legal framework and management requirements for implementing and operating the Zugdidi geothermal production and district heating distribution system, maintenance practices, staffing and training needs, etc.
   c. Description of the legal requirements and framework for company relationships with local authorities, the Government of Georgia, international business and the EBRD.

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3. Preparation of tender documents if project is approved by EBRD.

4. Preparation of Final Report.

Also attached is a translation from Russian of a report titled "Assessment of Operational Reserves (Capacity) of Thermal Water in Zugdidi-Tsaishi Deposit (Republic of Georgia)" published October, 1984. This report provides a great deal of history on the development of the resource, the geology and geochemistry up to that time.

We have also included about thirty pages of miscellaneous documents previously prepared over the past year which we hope you will find of interest to point out the importance of the success of the Zugdidi project to Georgia. Some of this information has been provided to Ambassador Courtney.

Zugdidi is about 2 Km from the border to Abkazia and the Inguri hydro power plant and is of political importance for maintaining stability in the region. Zugdidi is economically important because of the large number of commercial enterprises located in the region. These enterprises are key elements in implementing the institutional reforms necessary for privatization and developing a strong free market economy. Already there is strong interest by German companies in forming joint ventures with these enterprises.

The success of these reforms, encouraging foreign investment and redevelopment of the infrastructure, will strengthen the ability of the local government to provide the cash flow necessary to repay the EBRD loan.

If you have any questions, please call me at (202) 408-6831, x14.

Prepared by:
John E. Hallberg, P.E.
Task Manager

Sincerely,

Douglas D. Tuckhorn
Project Director-Caucasus

Attachments
c: P. Feeney, USAID, (T)
J. Hallberg, BREI (NJ) (w/o attach)
L. Hultin, EBRD (UK)
Z. Menteshashvili, BR (T)
W. Smith, USAID (Y)
G. Weynand, USAID (DC)
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Development, Investment & Engineering
ArCi Consulting

Delivery Order 25.
Zugdidi Geothermal Assessment

Subtask I:
Assessment of Zugdidi Geothermal District Heating

Subtask II:
Preliminary Financial Analysis

Technical Report

Draft

Prepared under subcontract to Burns & Roe Entarprises, Inc

Tbilisi, 1997

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BUDGET ESTIMATE

Gas Boiler $24/GCal Cost

Zugdidi

Chapter 1	Rehabilitation Wells	130,000	
Chapter 2	Rehabilitation Piping/Pumps	509,000	
Chapter 3	Heating Station	630,000	
Chapter 4	Distribution	560,000	
Chapter 5	Interconnection	35,000	
Chapter 6	Testing, Engineering, Construction Management, Licenses	850,000	
		$2,679,000	$7.2/GCal = Cost
		Revenue @	$15/GCal = 12.5 yr
		Revenue @	$20/GCal = 7.2 yr

Tsaishi

	Agricultural Complex	$16,600,000	

Chapter 1	Rehabilitation Wells	234,500	
Chapter 2	Rehabilitation Piping/Pumps	278,000	
Chapter 3	Heating Station	752,400	
Chapter 4	Distribution	293,600	
Chapter 5	Interconnection	205,000	
Chapter 6	Testing, Engineering, Construction Management, Licenses	977,700	
		$2,741,200	$3.12/GCal = Cost
		Revenue @	$12.50/GCal = 3.2 yrs

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Geothermal Water Reserves in Georgia

Of all the types of the untraditional energy sources, the usage of earth depth heat is the most promising. This is due to its accessibility, wide distribution in the earth core and possibility to avoid, almost completely, pollution of the environment.

According to the present hydrogeological data, total reserve of thermal waters in Georgia equals 220-250 million m^3/year, with temperatures - 50-110^{0}C.

The territory of Georgia is divided by the following five geo-tectonic zones: 1) Great Caucasus crystal substrate ground water zone; 2) Great Caucasus south slope zone of the water-head systems; 3) artesian basin area of the Georgian clod; 4) Achara-Trialeti zone of water-head systems; 5) ground water zone of Artvino-Bolnisian clod. Thermal waters are distributed within all these hydro-geothermal zones except the first one. In the other four zones there are hydro-geological areas of water-head systems that have specific, individual, hydro-dynamic, hydro-chemical and geothermal properties and conditions. Georgian clod is especially rich in thermal waters. Here we have a series of artesian basins united into an integral, large Rioni basin, as well as water-head systems of Achara-Trialeti folded zone.

In Table 1 we can see estimated amount of water reserves in the basins. Though, as some of the promising reserves of thermal water have not been investigated yet, their potential is unknown.

Table 1

Expected Reserves of Thermal Water in the Basins

Basins	Expected Reserves, mln. m^3/year
Great Caucasus south slope	2
Abkhazia	34
Kolchida	31
Imeretian	50
Achara-Trialeti (without the area near Tbilisi)	86
The area near Tbilisi	40
South Georgian	7
Total in Georgia	250

Total area of the main basins with thermal waters equals 22 450 km^2, and the expected thermal water debit is equal to 570-580 thousand m^3/day. These reserves might play an important part in the development of the energy sector of Georgia.

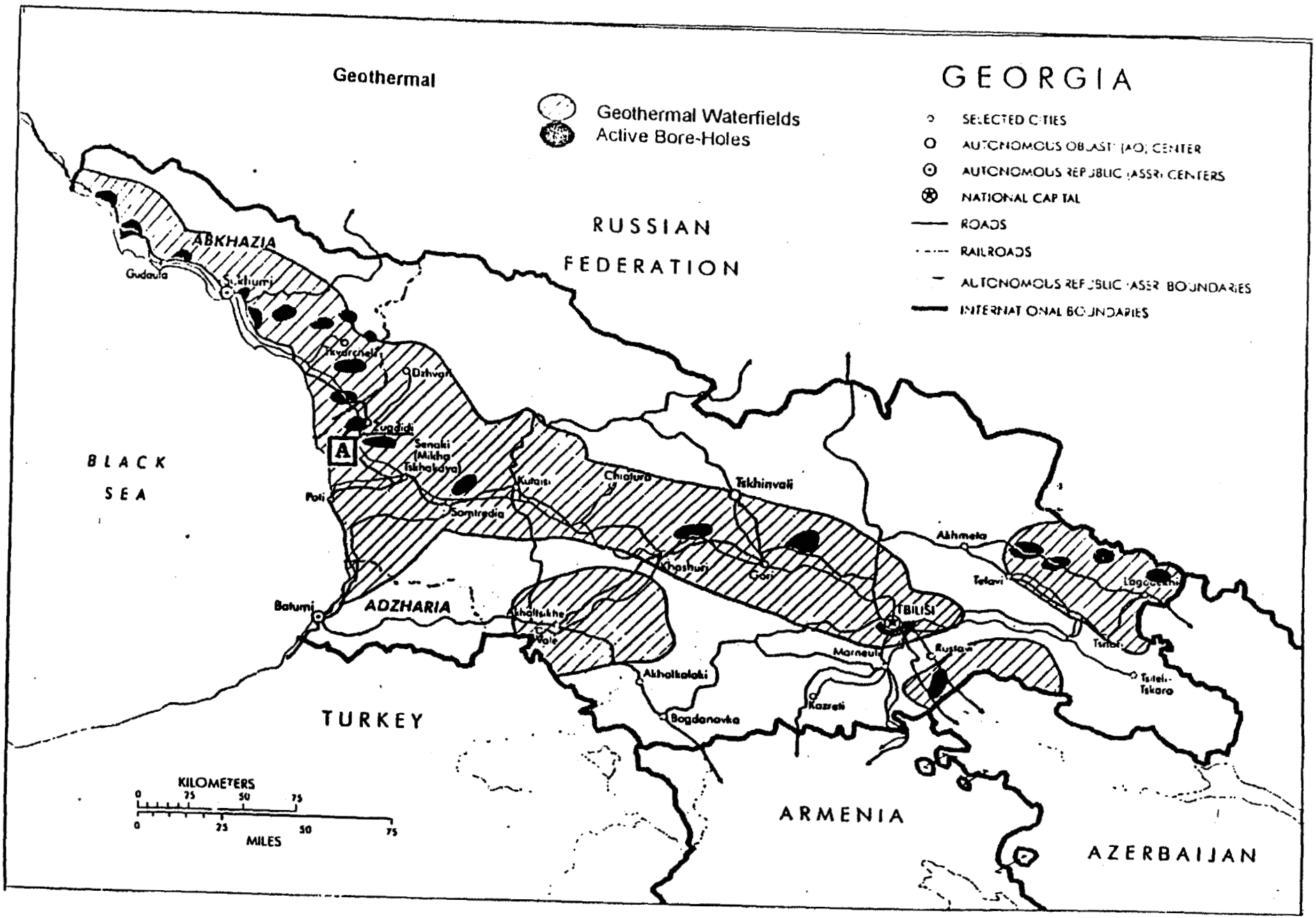
Geothermal
Geothermal Waterfields
Active Bore-Holes
GEORGIA
SELECTED CITIES
AUTONOMOUS OBLAST (AO) CENTER
AUTONOMOUS REPUBLIC (ASSR) CENTERS
NATIONAL CAPITAL
ROADS
RAILROADS
AUTONOMOUS REPUBLIC (ASSR) BOUNDARIES
INTERNATIONAL BOUNDARIES
RUSSIAN
FEDERATION
ABKHAZIA
Gudauta
Sukhumi
Tkvarcheli
Dzhvari
Zugdidi
A
Senaki
(Mikha
Tskhakaya)
Poti
Kutaisi
Samtredia
Chiatura
Tskhinvali
Khashuri
Gori
Akhmeta
Telavi
Lagodekhi
TBILISI
Rustavi
Marneuli
Tsiteli-
Tskaro
Batumi
ADZHARIA
Akhaltsikhe
Vale
Akhalkalaki
Bogdanovka
Kazreti
BLACK
SEA
TURKEY
ARMENIA
AZERBAIJAN
KILOMETERS
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Table 2

Characteristics of the Main Basins of Geothermal Water in Georgia

N	Name of the Basin	Area (km^2)	Expected debit (thousand m^2/24 h)	Established reserves (thousand m^2/24 h)	Thermal water tempera-ture, ^0C	Districts
1	Bzibi	1900	50-60	15	80	c.Gagra
2	Kodori	2750	50	15	60-90	Gulripshi, Ochamchire, Gali
3	Kolchida	3000	100	14	50-120	c.Poti, Khobi, Zugdidi
4	Samegrelo	2000	120	12	90-100	Zugdidi, Senaki, Tsalenjikha
5	Tskhaltubo	1650	30	17	60-80	c. Kutaisi, Khoni, Samtredia
6	Argveti	700	10	5	50-60	Zestaphoni
7	Akhaltsikhe	750	10	3	70-80	Akhaltsikhe
8	Kartli	3000	40-50	11	70-90	Gori, Khashuri
9	Tbilisi	2800	100	8	60-90	Tbilisi
10	Marneuli Gardabani	1500	30	5	80-100	Marneuli, Gardabani
11	Alazani	2400	30	6	80-100	Telavi, Gurjaani, Lagodekhi
	Total	22450	570-580	101		

Conditions of Disposition, Temperature and Main Physical and Chemical Properties of the Thermal Waters

Up to now thermal waters were produced in Georgia from about 2000-3000 m depth. With the development of the depth drilling, the depth will reach 3500-4000 m and we can expect a substantial increase in output of high temperature water sources.

Thermal waters with wells of a substantial debit and high temperature can also be used in the energy sector. While using thermal waters it is necessary to take into consideration not only the debit, temperature and depth but also their mineralization.

By chemical properties the thermal waters in Georgia are of sulfate-chloride-calcium, hydrocarbonate-natrium, carbonate-hydrocarbonate-natrium type.

Gas composition of these waters is mainly nitrogen, nitrogen-methane and methane. Sometimes they have small amount of carbonic-acid (well No.2 in Kindgi, well No.3 in Okhurei-Ochamchire region) and sulfur-hydrogen (well No.2 in Menji-Senaki region, c.Tbilisi and Tsaishi-Zugdidi region).

In most cases thermal waters in Georgia contain micro-components - iodine, bromine, boron etc. which together with temperature, gas composition and weak radioactivity determine medical properties of the waters (Tskaltubo district near Kutaisi, Tsaishi - Zugdidi district, Nakalakevi - Aspindza district, Menji - Senaki district, Samtredia - Samtredia district, Tbilisi, etc.).

Thermal waters of Georgia in general have low mineralization. According to the data of the Department of Hydrogeology and Engineering Geology of Georgian Academy of Sciences, more than half of thermal waters in Georgia have mineralization below 1 g/l, which makes them more convenient for practical utilization. In most cases general mineralization varies within 0,4-2,2 g/l.

Thus, thermal waters in Georgia in most cases do not have high mineralization and gas contents. Though they contain active elements, such as - SO_2, CO_2, Na, Ca, Mg, which cause saline deposition and corrosion of pipes, have negative effect on thermal and hydraulic regime of the circulation systems.

In Table 3 we give geothermal properties of thermal waters in Georgia (on the example of one well for each deposit).

Table 3

Main Characteristics of Geothermal Waters of Georgia

N	Name of the Basin	District	Debit (m^3/day)	Thermal Water tempera-ture (^0C)	Pressure (Atm)	Minera-lization (g/l)	Gas Composition
1.	Gagra	vicinity of t.Gagra	500	19	3.8	0.7	N_2
2.	Pitsunda	- " -	1500	19	-	0.5	N_2
3.	Gudauta	Gudauta	800	42	1.0	0.4	N_2
4.	Dranda	Gulripshi	1500	91	9.8	1.8	N_2
5.	Kindga	Ochamchire	2400	100	4.5	1.9	CO_2
6.	Okhurei	- " -	6000	100	10.2	0.9	CO_2
7.	Rechkhi	Gali	1400	57	-	0.5	N_2
8.	Saberio	- " -	600	20	-	0.6	Na_2CO_3
9.	Bia	Khobi	3000	82	-	-	N_2, CH_4
10.	Kvaloni	- " -	1400	97	0.5	0.4	N_2, CH_4
11.	Kulevi	- " -	800	50	-	-	H_2S, N_2
12.	Zugdidi	Zugdidi	1800	86	0.4	0.4	H_2S, N_2
13.	Anaklia	- " -	1400	77	0.3	0.5	N_2, CH_4
14.	Tsaishi	- " -	2000	82	-	3.3	H_2S, N_2
15.	Poti	vicinity of t.Poti	1000	62	-	1.3	N_2
16.	Menji	Senaki	2400	57	-	-	H_2S, N_2
17.	Batumi	vicinity of t.Batumi	1200	60	-	1.1	N_2
18.	Samtredia	Samtredia	2500	50	-	0.4	N_2
19.	Vani	Vani	1000	47	1.1	0.4	CO_2N_2, CH
20.	Adigeni	Adigeni	800	100	1.5	1.3	N_2
21.	Akhaltsikhe	Akhaltsikhe	940	98	1.1	4.7	CO_2, Cl, B
22.	Nakalakevi	Aspindza	1000	82	2.1	3.2	CO_2
23.	Tmogvi	- " -	800	100	1.3	2.1	CO_2
24.	Akhalkalaki	Akhalkalaki	600	100	1.4	0.4	Na
25.	Nino-tsminda	Ninotsminda	700	84	1.3	0.5	N_2
26.	Kharagauli	Kharagouli	2400	57	-	-	N_2
27.	Tbilisi	vicinity of Tbilisi	800	68	13.2	0.6	H_2S, N_2
28.	Gardabani	Gardabani	600	50	4.2	0.4	CH_4, CO_2
29.	Kardanakhi	Gurjaani	1200	46	-	0.3	N_2
30.	Chandari	- " -	600	46	-	-	N_2, H_2S, CH_4
31.	Kvareli	Kvareli	4000	46	-	0.2	N_2, H_2S, CH_4
32.	Lagodekhi	Lagodekhi	5000	52	-	0.1	N_2
33.	Tskhaltubo	vicinity of t.Kutaisi	500	37	-	2.3	N_2

Experience in Geothermal Water Utilization

For 1992 the thermal water production in Georgia was carried out at 23 water reservoirs found in Zugdidi, Gali, Ochamchire, Senaki, Samtredia, Aspindza, Vani, Khobi and Tbilisi districts. The water was used for heating hot water supply, as well as for technical and biological reasons. According to 1989 year data the water was mainly used for communal services (60%). 25-15% of geothermal water was used in agriculture and industry respectively. The sphere of geothermal water utilization was not extended only because of the low level of development of engineering problems for geothermal water usage and effective utilization of geothermal resources. For example, in most of the large reservoirs there were only few exploration wells, which could not provide regular production of thermal water. No measures were taken to protect any of these wells from depletion or to restore the resources. In most cases thermal water that had temperature above 40-50^{0}C was directed to water reservoirs, thus causing thermal pollution of the surface waters.

In Georgia, at the end of 80-ies several big projects were being worked out. Their purpose was to use geothermal water heat in large greenhouses. But unfortunately these projects did not pay sufficient attention to the full-scale utilization of geothermal energy.

We must also mention here the possibility of chilling by means of geothermal water heat. Calculations show, that only on the basis of Kindga wells, that are in operation now, it is possible to build fruit and vegetable storage with the capacity of 20 thousand tons. Though the largest consumers of geothermal sources in agricultural sector are greenhouses, cattle breeding farms, fisheries and enterprises of primary processing of food products, which can substantially rise the efficiency of geothermal heat utilization. All the above mentioned measures will make it possible to avoid seasonal nature in consumption of thermal waters and facilitate to use their heat potential at the maximum possible level.

Efficiency of thermal water utilization depends upon a number of interrelated factors - technical, economic and environmental. The technical factors are: possibility of maximal heat extraction by application of various heat supply schemes and combinations of different types of consumers, thermal water quality, necessity and possibility of its purification, rational usage of the existing wells and drilling of new ones. The main economic factors are: the cost of well drilling, capital investments to heat and chill supply systems, general energy indicators and the specific features of the economic development of the district. The environmental factor is thermal pollution of the environment. In order to prevent it, it is necessary to resolve the problems of reinjection of the thermal waters that have already been used.

Analysis of the modern state of geothermal resources' utilization of Georgia enables us to identify a number of problems that hinder the development of geothermal energy branch. Namely these are: existence of seasonal consumers, insufficient output capacity of some of the wells, lack of consumers or their reluctance to receive thermal

water. Tbilisi is an exception: it can consume more thermal water than the existing wells are capable to supply.

In order to increase the number of useful operating sources, first of all it's necessary to solve the problem of reinjection of discharged thermal water, reach higher level of utilization of their heat potential and increase of the operation hours of all geothermal sources of Georgia. Utilization of geothermal waters must be carried out taking into consideration their thermal potencial, chemical properties, gas contents and results of tests of their corrosion harshness. The method of thermal water utilization must be chosen based on these data: a) preliminary treatment, b) use of heat-exchanger, c) direct supply of geothermal water to the heating system, d) direct supply of geothermal water to the hot water supply.

For rational and combined utilization of thermal waters it is necessary to work out projects of construction of greenhouses, poultry farms, grain, fruit and vegetable dryers, soil heating and warm irrigation, communal services and local industry enterprises near geothermal resources. It is also advisable to build large water reservoirs on the basis of discharged thermal waters for fisheries. Such an approach will enable us to avoid seasonal character of thermal waters utilization and use their thermal energy at maximum capacity.

Environmental Aspects of Thermal Water Utilization

Due to low mineralization and gas contents of thermal waters in Georgia the amount of deposits in the process of operation is low. Notwithstanding this factor, some preliminary thermal water treatment is necessary for its successful utilization.

During the recent year, a number of experiments on different methods of preliminary water treatment were carried out in the former Soviet Union. The methods that have been studied are: stabilization method (Krasnodar Scientific Research Institute of Agriculture); water softening (Department of Scientific Research on Water Supply and Sewage Systems at the Georgian Technical University); dephenolization and degazation methods (Mingasprom); method of deep removal of hydrogenated sulphur and iron (Moscow Engineering Institute).

Of the above mentioned method only the method of water softening was tested and implemented in Georgia. This work was carried out in order to work out such reagents, which would guarantee timely softening and desactivation of water, (removal of radium and radon), prevention of corrosion of metal parts of heating systems and reduction of costs for efficient utilization of geothermal water. A coagulant was worked out with the following ratio of components in percentage of thermal water weight: oxalic acid - 2,6; phosphoric acid - 1-3; ammonium hydroxyl - 4-6; gypsum - 0,1-0,2; the rest is water. The coagulant permits to soften geothermal water from high hardness to zero. When it is mixed in 0,3-0,5% amount of the total volume of treated water, it also removes radium and radon, causing desactivation of water and prevents corrosion of metal pipes. The technology implies pouring of the

coagulant into the treated geothermal water, mixing, settling in a settling basin and supply of thermal water to consumers after having passed the appropriate filter.

The described method was implemented and successfully used at one of the greenhouses in Kindga, in Ochamchire district. In order to achieve removal of phenols from water, Mingasprom was involved and worked out the method of dephenolozation of discharged water by means of chemical effect on phenols - oxidation of phenols by means of sodium-hypochloride (NaOCl). But this reagent is not produced in concentrated form as it is expensive.

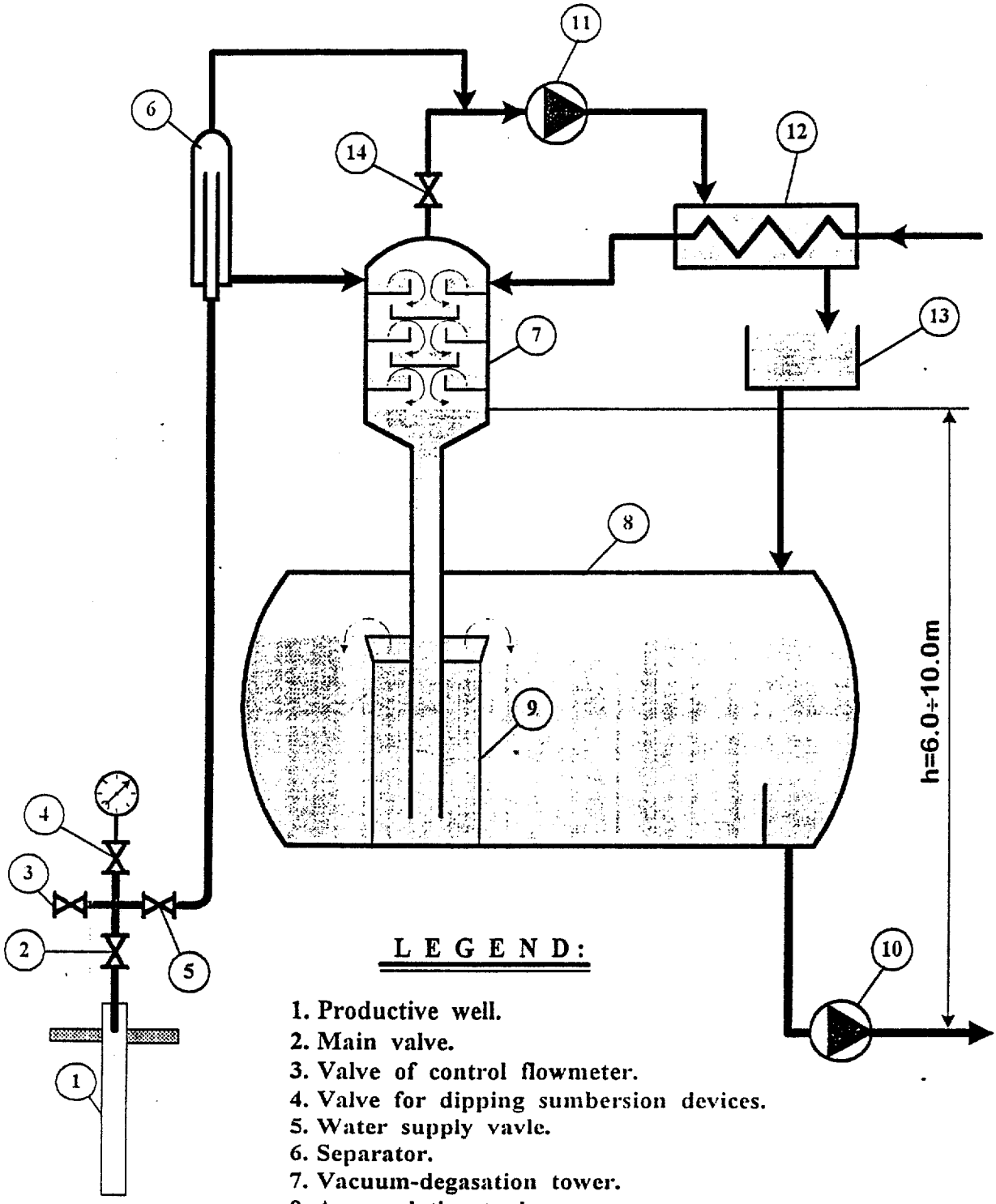
Mingasdprom also designed and built a special apparatus - aerator for mixing liquids with gasses. In this device the geothermal water is mixed with air, reaching a high level of oxidation and phenol blowing.

Geothermal waters, which correspond to the requierements for pottable water and their mineralization does not exceed 10 g/l, can be used in the direct schemes. If geothermal water does not satisfy the above mentioned conditions, but has high thermal potential, it can be used in heating-chilling supply systems through an intermediate heat-exchange equipment.

Most wide-spread method of neutralization of geothermal water harshness in Georgia is the degazation method.

In the picture a scheme of degazation equipment is presented.

Principal scheme of vacuum-degasing device on head-part of well.



LEGEND:

1. Productive well.
2. Main valve.
3. Valve of control flowmeter.
4. Valve for dipping sumbersion devices.
5. Water supply vavle.
6. Separator.
7. Vacuum-degasation tower.
8. Accumulative tank.
9. Hydroclutch.
10. Pumping station (first stage).
11. Vacuum pump.
12. Condensate cooler.
13. Condensate tank.
14. Valve for regulation of vacuum level.

Organizational Structure of Geothermal Water Utilization

Practical utilization of geothermal waters in energy sector started in Georgia in 1967, after the opening of Caucasian subsidiary center in Zugdidi to study and utilize underground thermal power (main office is in Makhachkala, Russia).

These subsidiary center was included into the State scientific-research enterprise "Sakburgeothermia", that was opened in 1973 in Tbilisi. "Sakburgeothermia" established six regional enterprises in Abkhasia, Kolkheti, Samtredia, Kharagauli, Kakheti and Tbilisi.

During the period of armed conflict in 1992-1993 enterprises of Abkhazia, Kolkheti (Zugdidi) and Samtredia enterprises was inflicted considerable material losses and at present they don't operate.

At present Tbilisi enterprise manages the operation of several wells with total discharge up to 4000 m^3/day. Private enterprise "Geothermia" operates these geothermal waters. At present Kharagauli enterprise operates only partially and supplies Kharagauli with hot water. Kakhetian enterprise is being conserved, and the enterprises, which were supplied with geothermal waters are not operating now.

So, at present state enterprise "Sakburgeothermia" is not operating and prospects of its activisation are doubtful. At the same time management of "Sakburgeothermia" is trying to hinder in every possible way transformation of enterprise into joint-stock company.

The only private company in Georgia, that is interested in study and utilization of geothermal power, is company "Geothermia". Active position of management of the company "Geothermia" resulted in municipal loan allocation for rehabilitation and improvement of hot water supply system on the base of Lisi deposit geothermal wells in Tbilisi. By the initiative of the company "Geothermia" the Parliament of Georgia (Committee for Environment Protection Problems and Utilization of Natural Resources) discussed prospects of intensification of geothermal resources study.

History of Development of the Zugdidi-Tsaishi Geothermal Deposit

Zugdidi-Tsaishi deposit of thermal waters was found in 1951 by well No. 1, drilled to explore coal deposits by the company "Kavkazuglegeologia". The well was drilled down to 824 m depth. During the drilling works at 707 m depht in the barrem lime there was obtained self-flow of thermal water with temperature up to 60^0C. At more depth the water temperature increased and reached 82^0 C. General mineralisation of water was 1,7 g/l. According to the data of 1952, operating supplies of the thermal waters were set in the amount of 2,600 m^3/daily at the temperature of 82^0C.

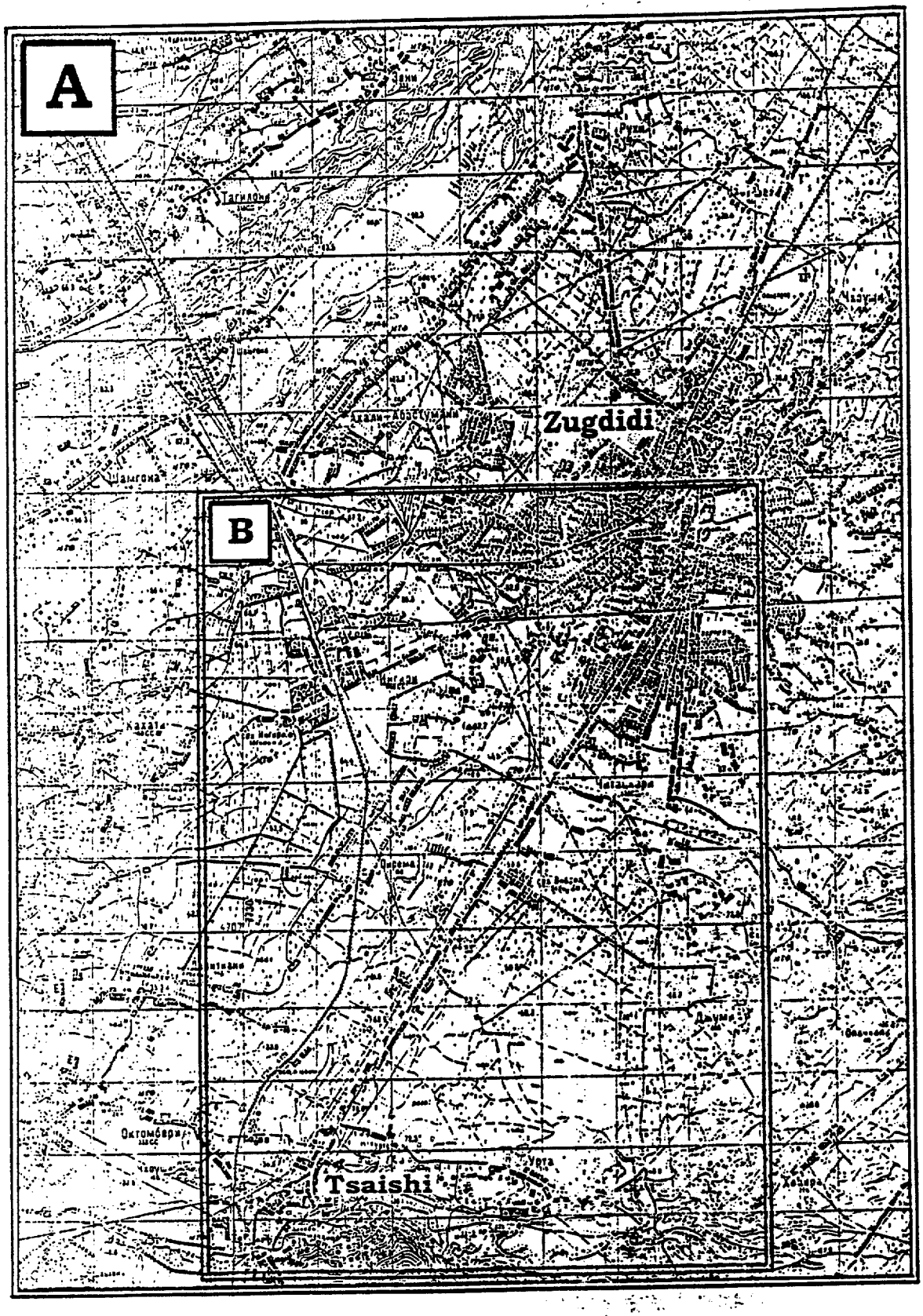
On the basis of the water there was built a balneological resort in village Tsaishi which is still operating. In 1964-1968 within the town Zugdidi the Georgian

Geological Department drilled three investigation wells (No. 1, 3, 4), from which the thermal waters with total volume of 6800 m^3/day were obtained.

Since 1975 besides the Geological Department which continues to explore thermal waters on the territory of Georgia, a large amount of deep drilling works were performed by enterprise "Sakburgeothermia").

Based on generalization of geological-hydrogeological data in 1989 amount of available thermal water was estimated as 14300 m^3/day.

Exploration in this area were continued till 1992. Currently there are 18 operating wells of various purpose in Zugdidi-Tsaishi deposit. Total flow of thermal water is 30000 m^3/day and temperature range is 82-106^{0}C.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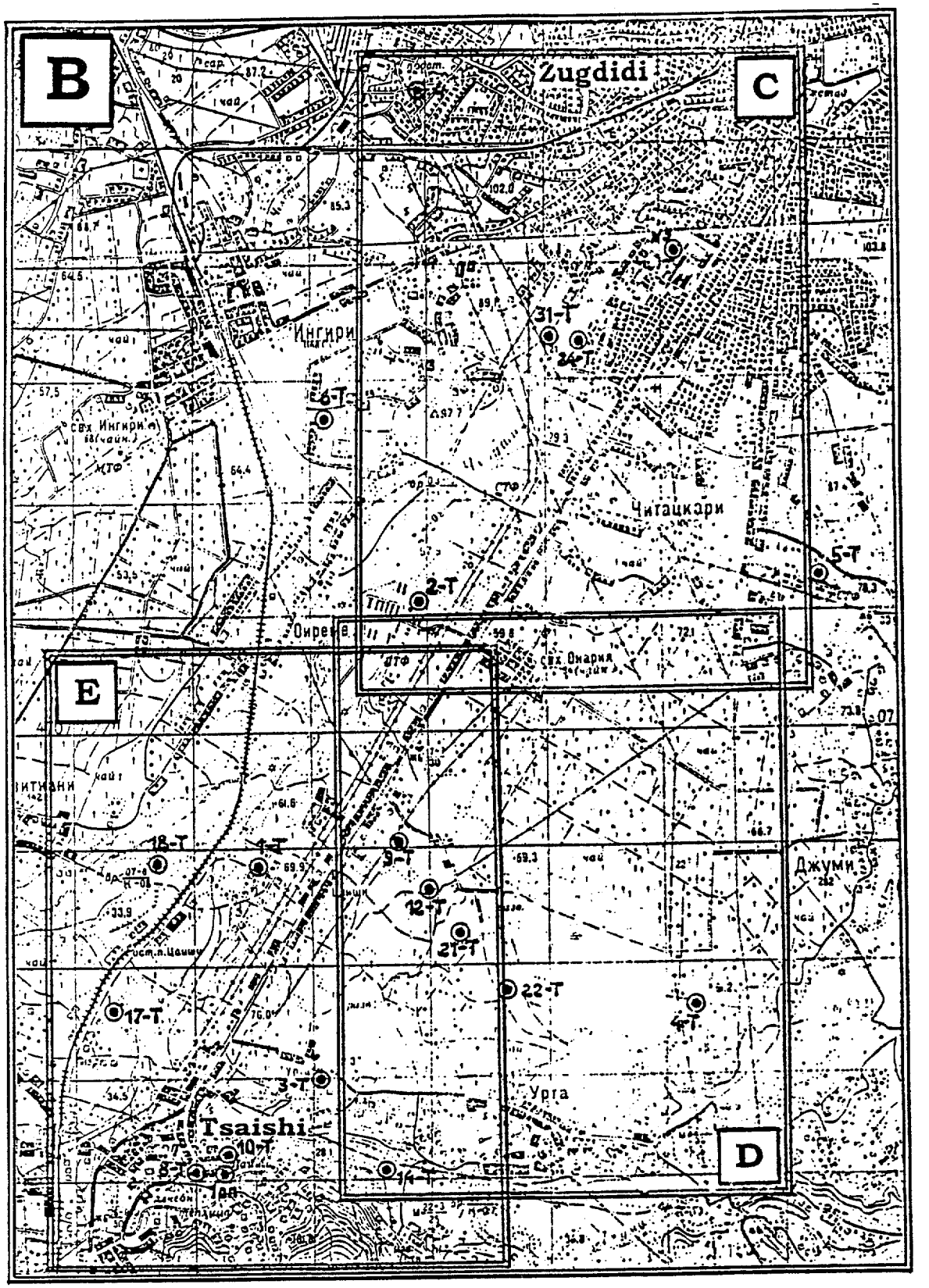
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Zugdidi
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6-T
5-T
2-T
18-T
4-T
9-T
12-T
21-T
22-T
17-T
3-T
10-T
8-T
1-T

General Review of Physical-Geographical and Climatic Conditions in Zugdidi District

Zugdidi-Tsaishi deposit of thermal waters is situated on the territory of the Zugdidi district of Georgia. It is located within Mengrelian artesian basin, between the rivers Ingiri and Tskhenistskali. The northern border of the basin passes along the southern slope of the Mengrelian mountain-chain, the southern border is represented by anticline folds in linked position (Satanjo, Urtine, Eki, Nokalakevi, Abedati).

Zugdidi and the adjacent villages (Tsaishi, Urta, Onaria, Odishi, Ingiri, Kakhati, etc.) are linked with other regions of Georgia by well developed highways. Besides, Zugdidi is linked with Tbilisi, the capital of Georgia by railway and in Ingiri, which is 10 km away from Zugdidi there passes railway, which connects Georgia to other CIS countries. Well developed power transmission line system provides power supply to the area. It is easy to solve the problem of technical and potable water supply to the site within the explored water intake location.

In the orohydrographic sense, within the area of explored geothermal water wells, there could be found: 1). high mountainous, almost inaccessible, landscape cut with numerous rivers, 2). erossion-hilled, terraced landscape, and 3). accumulative plain. High mountainous, almost inaccessible, landscape is developed in the north-east part of the region, mainly on the substraction of Cretaceous and Jurrasic deposits. Absolute altitudes of high mountainous area vary within 1,000 and 2,500 m.

The major orohydrographic item in this region is watershed mountain-chain between the rivers Tekhuri and Khobi. To the south from this region there is located hilly landscape with absolute altitudes of 600-1000 m. In the western and south-eastern parts of the deposit there are mountain-chains of medium height: Satanjo, Urta, Eki, Nokalakevi and Abedati.

Climate in Zugdidi district is subtropical, damp with warm winter and hot summer. The climate formation of the region is strongly influenced by the Black Sea. Average annual air temperature reaches 13-14^{0}C. The coldest month is January (average temperature in January varies between 4,5-5,4^{0}C). Absolute minimum of temperature in January reaches -14^{0}C. Absolute maximum of temperature in January is 22^{0}C. It starts to freeze in the region in December and stops in March. Periods without frost are long enough, on average 300 days annually. Years when the temperature does not go down below 0^{0}C are quite frequent. From February the temperature goes up and reaches maximum in August. Average temperature in this month is 22,7^{0}C. Absolute maximum of temperature of the air in the region is rather high and reaches 40^{0}C. Absolute minimum of temperature in August is 10^{0}C.

The musson winds are typical for the region. In winter there are winds from the east direction (winds from the ground), and from west in summer (from sea). In the region there are well developed day and night winds -breezes (in daytime wind blows from the sea, and at night-from the ground). Wind power is 1-2 m/sec.

Outdoor air temperature, ^0C																							
Average monthly temperature												Annual Average	Absolute minimum	Absolute maximum	Average maximum	Average for the coldest 5 days	Average for the coldest 24 hours	Average for the coldest month	Period, when the mean daily temperature </= 8^0C		Duration of the period with mean daily temp. </= 0^0C	Average outside air temperature measured at 1^{00} p.m.	
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII								Duration (days)	Average, ^0C		Coldest month	Warmest month
4.9	5.5	8.2	12.3	17.0	20.3	22.6	22.7	19.2	15.1	10.5	6.5	13.8	-19.0	40.0	27.8	-3.0	-6.0	2.5	101	6.4	0	7.3	26.3

Outdoor air temperature fluctuation amplitude, monthly mean / maximum, ^0C											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
7.1 / 20.0	7.6 / 19.7	8.6 / 19.6	10.8 / 23.8	11.3 / 22.9	10.8 / 21.6	9.4 / 20.0	9.7 / 21.1	10.1 / 22.3	10.1 / 20.5	8.4 / 20.1	7.4 / 17.4

Average monthly relative air humidity, %													Average relative air humidity at 1^{00} p.m.		Average amplitude of a relative humidity daily fluctuation in the warmest month, %
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average annual	of the coldest month	of the warmest month	
74	73	73	72	76	78	82	82	83	79	74	72	76	62	68	24

• Maximum weight of snow cover, kg / m^2	- up to 50.0
• Approximate date of creation and destruction of snow cover	- not regularly, there is no stable snow cover in some years.
• Average amount of annual rain precipitation, mm	- 1,616.0
• Daily maximum of rain precipitation, mm	- 196.0
• Freezing depth of ground, mm	- 0
• Average maximum speed of wind in January, m / sec.	- 3.1
• Average minimum speed of wind in July, m / sec.	- 0
• Total annual duration of calm, %	- 53.0

Precipitation amounts from 130 mm to 2300 mm annually. Precipitation mostly fall in September. Minor precipitation takes place in May. The days with precipitation are quite frequent, about 160 days annually. Maximum of precipitation is in morning and evening hours, minimum - during the night and day hours.

It does not snow regularly every year. Snow cover is not high, just several centimeters (2-10 cm). The average number of days with snow amounts to 15 days annually. Average relative humidity varies within the range of 70-80%. Thunderstorms are observed whole year round. The mists are rare. Hail is observed during the whole year. Hailstones are usually small and harmless.

Hydrography. There is a dense river net in Zugdidi district. There are also many lakes and marshes. The area is crossed by the rivers: Inguri, Jumi, Chkhoushi, Chanis-Tskali, Kulis-Tskali, Munchia, Rukhi, Didgali, Ergeta, Galentskali, Chitantskali, Mogiri, Umpia, etc. All the rivers are feed by rain and ground waters. The longest river of the region Inguri (213 km) is fed from the glaciers. Water collecting area is 4040 km^2. Average density of the river net basin is 0,59 km/km^2. Water level elevation starts at the end of March and maximum is reached in June-July. From November to April winter level of the river is set. In the region of geothermal wells the rivers Jumi and Chkhoushi can be named as relatively large ones.

Short Geological Description of the Zugdidi-Tsaishi Deposit

Zugdidi - Tsaishi thermal water deposit is located in the west part of the Georgian clod, which is a part of the Transcaucasian median massif.

The Transcaucasian intermontane region is divided by Adjaria - Trialeti fold zone into Georgian, Artvino-Bolnisi and Azerbaijan clod.

The Georgian clod occupies intermontane depression between the Great Caucasus and the Minor Caucasus in the elevated part of which the crystal substrate - Dzirula massif is seen. To the west direction clod is extended to the Black Sea region, while in the East it is extended to the Mtkvari depression.

Zugdidi - Tsaishi thermal water deposit is located in the region of two subzone contiguity - Odishi and Kolkhida.

Odishi subzone is one of the most distinctly expressed geostructural units of the western sinking of the Georgian clod. It includes the Central Megrelian syncline and Abegati, Nokalakevi, Eki, Urta and Satanjo anticlines surrounding it like a curtain.

Central Megrelian syncline is morphologically well expressed bowl type fold with a bit wavy surface. The north-eastern part is an integral monocline and south-western part is the curtain like breccia anticline folds - Abedati, Nokalakevi, Eka, Urta and Satanjo. Length and width of folds is the same and equals 40 km.

Almost all mentioned breccia anticlines are asymmetric. Their north-west wings are inclined by 30-40^0 angle and south-east ones - by 70-75^0 angle. The folds are morphologically clearly expressed and form Abedati, Urti and Eki mountain chains. Length of Abedati anticline is 15 km, Eki - 12 km and Urta - 20 km.

There are many other minor sinclinal and anticlinal folds that are formed within the Megrelian artesian basin.

Within the region there are a lot of disjunctive dislocations. Most of them are formed on the northern wing of Central Megrelian syncline and in the region of anticline folds. Tectonic dislocations of fault and thrust fault nature are found here.

Tsaishi thermal mineral water is related to the Urtin brachianticline, which is traced over the Urta mountains (466,4m) on the 20-25 km distance between villages Tsaishi and Sagigiberio. The fold axis has the form of an arc, which is slightly bended towards the South, passes to the southern slope of the mountain range. The north-east wing of the Urta anticline falls under 35-40^0 angle and the north west one - under 50-60^0 angle.

In the south-west direction from the river Dzhumi valley the fold is gradually sinking and is ended periclinely in the vicinity of village Sakharbedio in the pontian layer. At western border of village Tsaishi, the brachianticline is split by the eruption of submeridian stretch. On the lowered western block the extension of fold is overcovered by powerful quaternary cover.

The well 1-op gave us interesting data on structure of anticline. The well allowed to find presence of eruption with vertical amplitude of 550-600 m. Zugdidi anticline (dimensions 7,2 km x 2,6 km, amplitude 300 m) is located to the North-East from Tsaishi anticline.

From stratigraphical point of view cross section of Zudgigi geothermal deposit contains wide spectre of geological sediments from Liossial to Pleocene period. Section is covered by powerful Quarternary alluvial, delluvial, eluvial and palustrine formations, which are alternating frequently in both horizontal and vertical directions. There are 8 water-bearing horisons in these geological sediments and they are main sources of water supply to various towns and villages situated on the Kolkheti Plain.

Within the given section the Neocomian sub-stage of Cretaceous system is most interesting for us as main thermal water bearing horizon. Description of this layer follows:

There are transgressive layers of Lower Cretaceous deposits over the mixed color series and at several places on Bajocian formations. These layers are divided into three parts: Neocomian sub-stage, Aptian and Albian stages.

Neocomian sub-stage is represented by bedded light gray cryptocrystal, dolomite, cracked limestone. The Medium part of Neocomian suite is represented by the Urgon facies (Barremian stage), which consists of massive, thick layer, fractured, crystal and dolomatized limestone. The upper part of the section consists of bedded, marl, pelitomorphic limestone.

Neocomian deposits are main water bearing layers within the region. Clay deposits of mixed color suite of the Kimmerian Tithonian Stage form a water impermeable bed of this horizon and clay-marl deposits of Aptian-Cenomane period form water impermeable roof of this horizon. According to drilled wells total thickness of Neocomian deposits varies from 400 m to 900 m.

Feeding area of this horizon is situated in northern wing of Central-Megrelian syncline (2000 m). Then Lower-Cretaceous limes deepen towards the south and reach 2500-5000 m depth in the central part of artesian basin. This large difference between the feeding and discharge levels determines high head of thermal water of Lower-Cretaceous horizon. Water temperature in these sediments varies from 80^0 to 106^0C. By chemical composition they belong to sulphate-chloride calcium-sodium or chloride-sulphate calciul-sodium type of waters. Their mineralization varies in 0.9-2.4 g/l range.

Decrease of mineralization and respective decrease of contents of certain ions takes place from the South to the North, i.e. from Tsaishi to Zugdidi direction. Particularly, general mineralization of the extreme south well of the deposit, Tsaishi No 10-t in certain samples reaches 2.4 g/l and mineralisation of the most northern well Zugdii No. 3 decreases down to 0.9 g/l. Correspondingly, certain ions content also decreases from the south to the north, for example, chlorine content varies from 632 mg/l to 113 mg/l.

Comparison of chemical element composition of waters from geothermal wells of Zugdidi-Tsaishi deposit with chemical composition of surface waters shows that waters from Tsaishi wells No. 1-t and No. 2-t and Zugdidi well No. 3 are relatively of poor content of micro-elements compared to waters from Tsaishi wells No. 8-t and No. 10-t.

Chemical composition of thermal water in Zugdidi-Tsaishi deposit

Composition / Well No.	Content mg / litre				
	No. 1-op Tsaishi	No. 1-t	No. 2-t	No. 3-t	No. 8-t
1	2	3	4	5	6
Lithium, Li		0.9	0.9	-	0.7
Ammonium, NH_4	0.4	0.7	0.7	0.4	0.4
Sodium, Na	101.2	110.0	92.0	96.6	105.2
Potassium, K	33.7	24.0	23.0	31.7	32.1
Magnesium, Mg	29.2	34.1	52.3	45.0	26.2
Rubidium, Rb	-	0.04	0.04	-	0.03
Calcium, Ca	262.0	232.0	212.0	286.0	269.2
Strontium, Sr	No	No	No	No	No
Ferrum, $Fe^{\cdot\cdot}$	No	Trace	0.17	No	No
Ferrum, $Fe^{\cdot\cdot\cdot}$	No	0.64	0.57	0.57	No
Manganum, Mn	0.1	0.1	0.1	No	No
Copper, Cu	0.1	0.1	0.1	0.1	0.1
Molybdenum, Mo	No	No	No	No	No
Zink, Zn	0.1	0.1	0.1	0.1	0.1
Lead, Pb	No	No	No	No	No
Selenium, Se	No	No	No	No	No
Fluorine, F	1.9	1.6	1.2	1.6	1.7
Chlorine, Cl	197.4	130.3	184.0	149.1	220.1
Bromine, Br	0.49	0.93	0.93	0.85	0.46
Iodine, I	No	0.30	No	0.08	No
Sulphate, SO_4	786.6	576.8	569.4	835.1	740.5
Hydrosulphate, HS	3.74	2.55	1.02	3.42	3.5
Hydrocarbonate, HCO_3	150.0	146.4	146.1	155.6	134.2
Carbonate, CO_3	No	No	No	No	No
Arsenic, As	No	No	No	No	No
Hydrophosphate, HPO_4	0.014	0.014	0.014	0.014	0.014
Nitrate, NO_3	No	No	No	No	No
Nitrite, NO_2	No	1.26	1.42	1.48	No
Boric acid, H_3BO_3	No	No	No	0.8	No
Silicic acid, H_2SiO_3	64.0	74.0	44.8	76.8	76.0
Mineralisation, M	1,634.7	1,291.2	1.359.0	1,660.0	1,579.0
Solids	1,540.0	1,290.0	1,256.0	1,500.0	1,670.0
pH	6.6	6.2	6.9	6.6	7.3
Phenic acids	0.024	0.022	0.021	0.025	0.010
U	$0.1x10^{-4}$	$0.1x10^{-4}$	$0.1x10^{-4}$	not determined	$0.1x10^{-4}$
Ra	$0.7x10^{-9}$	$0.3x10^{-9}$	$0.4x10^{-9}$	not determined	$0.5\ x10^{-9}$

Comparison of compositions of Zugdidi-Tsaishi thermal water and surface water

Elements	Composition, mg / litre					
	Surface water	Tsaishi				Zugdidi
		1-t	2-t	8-t	10-t	3
1	2	3	4	5	6	7
Argentum	0.00013	0.00024	0.00043	0.0017	0.0017	0.0023
Ferrum	0.67	0.24	0.41	0.28	0.25	0.23
Cesium	0.0002	0.00039	0.0006	0.0017	0.0018	0.00053
Cobalt	0.0009	0.000042	0.000075	0.0001	0.00014	0.000072
Zink	0.01	0.011	0.012	0.019	0.019	0.01
Rubidium	0.0015	0.021	0.017	0.03	0.028	0.011
Chromium	0.00018	is not determined	0.0009	0.0012	0.0052	0.0044
Sodium	6.3	78.2	82.9	173.6	368.0	75.9
Potassium	2.3	19.5	25.0	24.6	62.4	25.0
Calcium	15.0	187.4	192.4	276.5	280.6	164.3
Magnesium	4.1	36.5	34.0	43.8	51.1	34.0
Chlorine	7.8	141.8	134.7	301.3	638.1	113.4
Bromine	0.021	0.93	0.93	0.46	0.44	0.52
Iodine, I	0.002	0.30	No	No	No	No

By quantitative parameters content of micro-elements in water from the wells Tsaishi No. 1-t and No. 2-t and Zugdidi No. 3 is similar to one of surface waters.

At self-flow of thermal water no spontaneous excrection of gas was observed. The leading components of gas dissolved in water are Nitrogen (56-83% of vol.) and Carbon Dioxide (16-44% of vol.). Small amount of Methane (0.9-2.9% of vol.) is also present. Level of gas saturation is 20-24 cm^3/l.

Composition of dissolved gases in thermal water of Zugdidi-Tsaishi deposit

Well	Gas content cm^3/l	Solved gas composition and volume, %							
		CO_2	N_2	O_2	CH_4	C_2H_6	C_3H_8	$i\ C_4H_{10}$	$n\ C_4H_{10}$
Tsaishi 1-op	23	36.0	61.1	-	2.9	-	-	-	-
Tsaishi 2-t	20	15.7	82.9	-	1.4	-	-	-	-
Tsaishi 10-t	20	43.5	55.6	-	0.9	-	-	-	-
Zugdidi-3	24	41.1	58.9	-	-	-	-	-	-

All thermal waters of Zugdidi-Tsaishi deposit were tested for compliance with standards "Potable water". Results of these tests revealed that these waters are safe

from epidemiological point of view, are harmless by their chemical contents and have favourable organolepthic properties.

Bacteriological tests showed that these waters are not poluted and total amount of bacteria in 1 ml of water is less than 100, coli-titre index is exceeding 300.

Warm and hot mineral waters of Tsaishi deposit are very popular because of their balneological properties. The Institute of Resorts and Physical Therapy determined that baths of geothermal water from Tsaishi deposit gives good results in treatment of various deceases of peripheral neural system, muscular system, gynecological and skin deceases.

Hydrogeological and Geothermal Conditions of the Deposit

Zugdidi-Tsaishi deposit of thermal water is a part of hydrogeological area of Georgian clod artesian basins, and is related to the south-west part of Megrelian depression. The following waterbearing and waterproof complexes are identified in the basin:

1. Waterproof layer of upper-Jurassic multicoloured suite.
2. Waterbearing complex of lower-Cretaceous (Neocomian) deposits.
3. Waterproof clayish-marl layer of Apt-Alb and Cenomanian deposits.
4. Water-bearing complex of upper-Cretaceous - lower-Paleogene.
5. Waterproof deposits of lower Miocenian, Oligocene and upper-Miocene deposits.

Zugdidi-Tsaishi thermal water deposit is related to the lower-Cretaceous (Neocomian) deposits, represented by crack-cavern dolomites and limes, having high collective qualities. Upper Jurassic clays (multicoloured suite) are waterproof footing of waterbearing complex, the roofing is formed by the marl-clay Apt-Alb waterproof deposits, and above them comes the upper-Cretaceous-Paleocenian waterbearing complex with subthermal mineral waters.

Neocomian waterbearing horizon. Maximal thickness of Neocome in Megrelian depression is determined to be 1000 m. Thickness of these deposits in wells (Tsaishi-Zugdidi) varies from 369 m to 1059 m. Feeding region for Neocomian deposits is situated on the north wing of central-Megrelian syncline on 1200-1500 m altitude level, where the abundance of precipitation is exceeding 1500-2000 mm/year, which gives way to powerful streams of underground water in the Neocom layers. Water flows from the north to the south and south-east, along the slope of rocks. The discharge of underground streams of intermediate depth circulation mainly takes place in large river canyons as springs, the debit of which reaches 5-10 l/sec.

By their chemical composition waters of these springs are of hydrocarbonate-magnesium-calcium type. Mineralization equals 0,3 g/l. Their temperature varies from 5^0 up to 12^0C. Regime of this water is affected by precipitation. Especially large flows are observed in autumn and spring , the least ones - in summer and winter.

Summary Lithological-Stratigraphical Section of Zugdidi-Tsaishi Deposit.

System	Division	Stage	Depth	Thickness	Lithological Column	Short description of rocks
Miocene	Pleocene and Quertenary depositions.	Meotic, Pontic, Kimerian.	400	400		Alluvial, deluvial, proluvial deposition: pebble conglomerates, shingle, clay, loam sand. Sandstone, clay conglomerates, sandstone loam (meotic); Sandstone-clay rocks with limestone conglomerate interlayers (pontic). Clay, shingle, loam, limestone layers and others (Kimerian and Kulianic depositions).
	Upper and Middle Miocene.	Chockrak, Karagan-Konn(Sarmat)	1100	700		Thin-layered Carbonaceous clays with alternation of sandstones, and clay (lower part). Strong sandstones, sandstone clays and clayey gipsum (upper part).
	Oligocene and lower Miocene.	Khadum, Sakaraul, Katsakhuri.	1700	600		Dark-grey, brown-grey clays, light-grey loose sandstones, marl.
Cretaceous	Upper cretaceous.	Turon-Dat.	2250	550		Uniform powerful layer of white light limestones containing concretions of red silicon, white light-grey limestones without red silicon inclusions. Limestones in lower parts are pelitomorphic weak marl, thin-layered with marl interlayers.
	Middle Cretaceous.	Apt-alb-Senomanian.	2950	700		Thin-layered marl pelitomorphic limestones with thin interlayer of marl and sandstone limestones. Dark stratified clayey marls with interlayers of compact limestone like marls. Interlayers of clayey glauconite sandstones.
	Lower Cretaceous	Neocom	3700	750		Fractured limestones and dolomites with various granulation. White crystallic cavern limestones. Dolomites and dolomitic limestones.
Jurrasic	Upper Jurrasic		3725	25		Gipsum clays, sands and sandstones.

Large difference between the feeding and discharge levels determines the high head of thermal water. The water temperature rises due to the deep bedding of water-bearing complex and to the comparatively high geothermal gradient, which reaches 3,5-4^{0}C per 100 m in this region.

Since 1951 different organisations have drilled the deep wells for purposes of exploration of coal, oil or thermal water deposits. These are the wells No. 1, 3, 4 in Zugdidi region and wells No. 1-op, 1, 1a, 4 in Tsaishi. Since 1979 series of prospecting works were performed in Tsaishi region and the following geothermal wells were drilled: No. 1-t, 2-t, 3-t, 4-t, 5-t, 6-t, 8-t, 9-t, 10-t, 12-t, 13-t 14-t, 17-t, 18-t, 21-t and 22-t. High temperature (82-106^{0}C) geothermal water was found in almost all wells. All these wells are situated on 29-130 meter altitudes over the sea level.

Partial discharge of thermal waters from productive (Neocomian) horizon is going through regional Tskhakaia-Tsaishi and Poti-Abedati breaking that borders Megrelian syncline from the West, South and East. Presence of these breakings was determined by Tsaishi wells and structural well that was drilled in town Tskhakaia. Amplitude of rock displacement exceeds 1000 m. In some places connection of underground waters of rised and lowered parts of complex is broken.

Large geothermal anomalies are related with zone of breakings and high temperature waters are found at relatively low depths.

In formation of temperature field of the arch-like bended anticlinal ridge the convective heat transfer is thought to be the most important process. In vicinity of Tsaishi deposit the temperature anomaly - 62^{0}C at the depth of 650 m was found. Surface waters are leaking at northern part of the Central-Megrelian syncline. Gradually penetrating through thickness of syncline, they enter then the anticline ridge. which is built by carbonaceous rocks of chalk, forming the Tsaishi thermal anomaly. Syncline is the "thermal buffer" for anticline ridge.

According to data obtained from wells the index of water conductivity for rocks of Neocomian complex varies in the range from 376 m^3/day to 572 m^3/day. Highest values are obtained within Megrelian syncline. Lowest ones for south-western and western deep-laying parts of the Rioni basin. Calculated parameters indicate on high and rather homogenous collection properties of lime rocks of this complex. For Neocomian complex (limestones) average general thermal conductivity is equal to 4.38+-0.54. According to researchers value of geothermal gradient varies in wide range depending on surface and depth.

Study of geothermal gradient distribution in stratigraphical horizons (limestones and dolomites) shows that general average gradient is equal to 33.48+-2.80. In regions, where cracked limestones of lower-Cretacous period come out to surface the water bearing complex receives its feeding from southern slope of the Great Caucasus. Width of limestones varies from 2-3 km to 10 km. Total area of water bearing limestones is equal to 698 km^2.

It was calculated that for above mentioned territory amount of atmospheric precipitation that filters through is equal to 25570 l/sec, i.e. 2211840 m^3/day. In average module of under-surface discharge, calculated by means of hydrographic net of rivers, equals to 14 m^3/sec. According to above mentioned data under-surface discharge (14 m^3/sec) amounts to 55% of precipitation infiltration value.

Estimation of Geothermal Water Reserve of the Zugdidi-Tsaishi Deposit

First estimation which was carried out in 1975 showed that the total debit of Zugdidi-Tsaishi wells was equaling to 9,078 m^3/day. During further researches within 1979-1984 there had been drilled six new wells of 1,200-1,900 meters depth. The obtained data enabled to reestimate the deposit output by November 25, 1989 status. In free self-flow of the wells the total debit increased up to 14,300 m^3/day with average mineralization up to 1.6 g/l, average temperature of thermal water in the well was 84 ^{0}C. By forecast of the state enterprise "Sakburgeothermia" which carried out the researches and assessments of the deposit reserves, the output of the studied wells shall not be changed for 25 years of operation.

Hydrogeologic observations proved that Zugdidi and Tsaishi water intakes represent one hydrodynamic system bordered by Tskhakaia-Tsaishi tectonic disturbances from the south. The tectonic crack influence on the deposit is vividly reflected on the degree of interrelation of the wells No. 1-OP, 8-T and 10-T. The distance between the wells No. 8-T and 10-T is 20 meters and well No. 1-OP is 50 meters away from them. However, even with the close neighboring location like this, well No. 10-T is fully isolated and does not react to changes of operation regime of well No. 1-OP and 8-T. This observation proves that wells No. 1-OP and 8-T are fed by geothermal waters from elevated tectonic block and well No. 10-T is related with the lowered block. Thus, it was concluded, that tectonic crack creates full isolation between the elevated and lowered tectonic blocks.

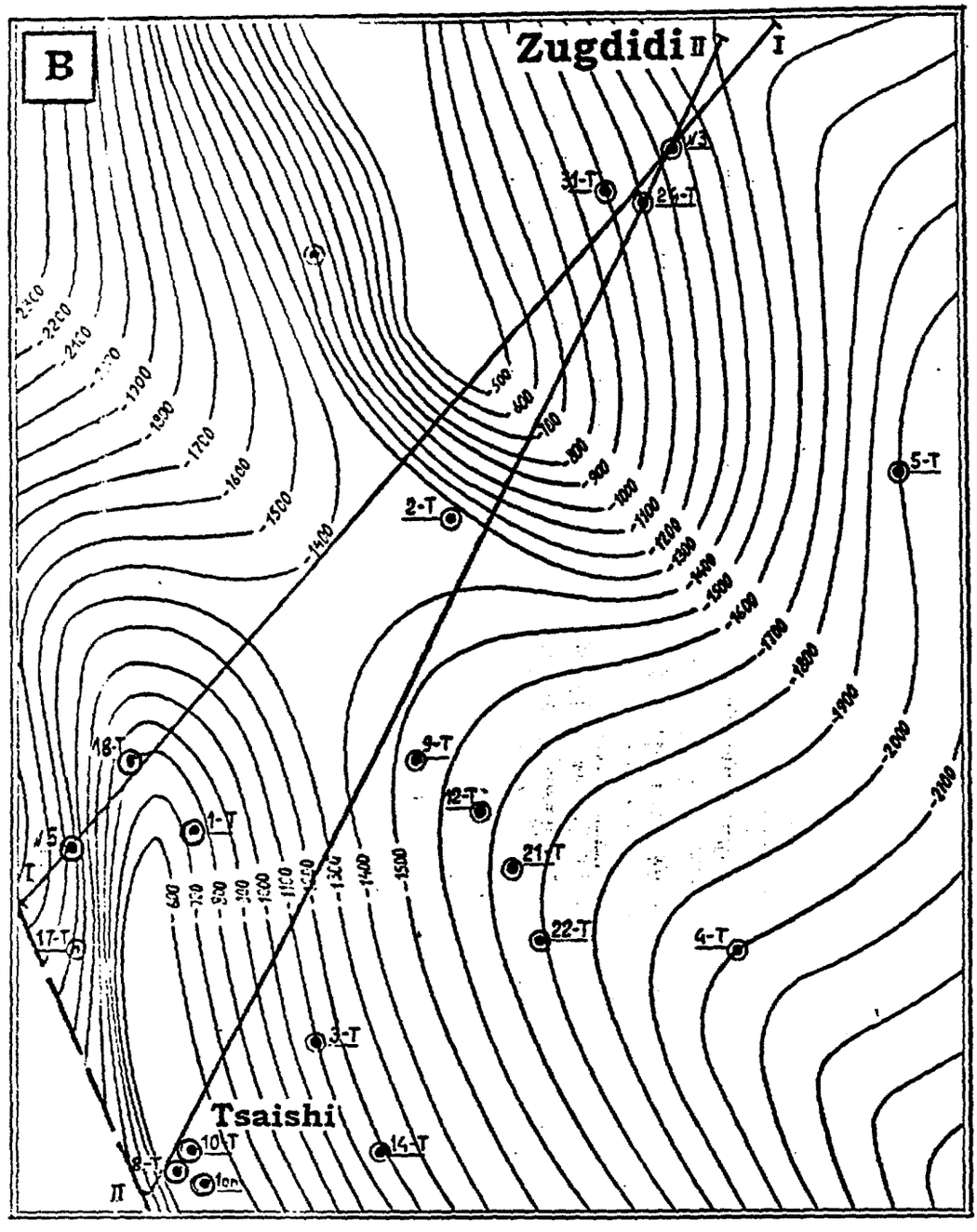
Analysis of long term observations proves that putting into operation of new wells, as a rule, causes significant debit reduction or full termination of self-flow in the wells drilled before irrespective to the distances between them. This serves as proof of high collecting properties of carbonate depositions of apt-neocom water bearing layer, unless its structure is damaged by tectonic cracks.

The last stage in the study of the deposit was carried out during 1985-1991 period. Some 12 wells were drilled with 2,100-2,800 meters depth and geothermal waters were found in all wells. Debit in each well is within 2,000-4,000 m^3/day and the temperature of water is from 84^{0}C up to 102^{0}C.

It should be noted that there is a lack of practical systematic study of the deposit. Therefore, such an approach is accompanied by definite negative consequences, for instance, operation of the wells located at the paper plant area in Zugdidi had to be ceased due to self-flow termination of these wells after drilling of new wells in Tsaishi region. The same happened to well No. 3 on the territory of town Zugdidi.

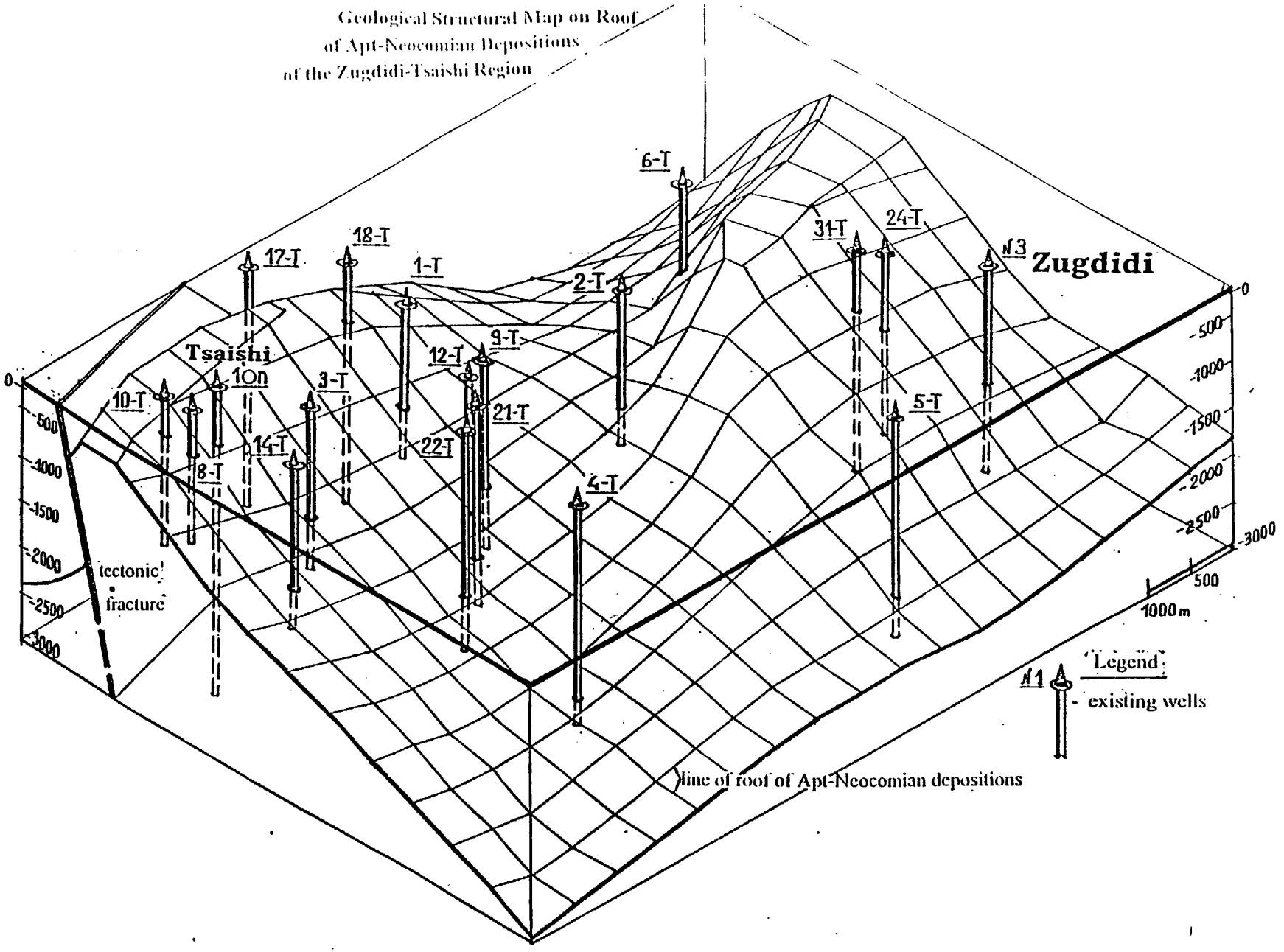
Geological Structural Map on Roof of Apt-Neocomian Depositions of the Zugdidi-Tsaishi Region

Scale 1:5000



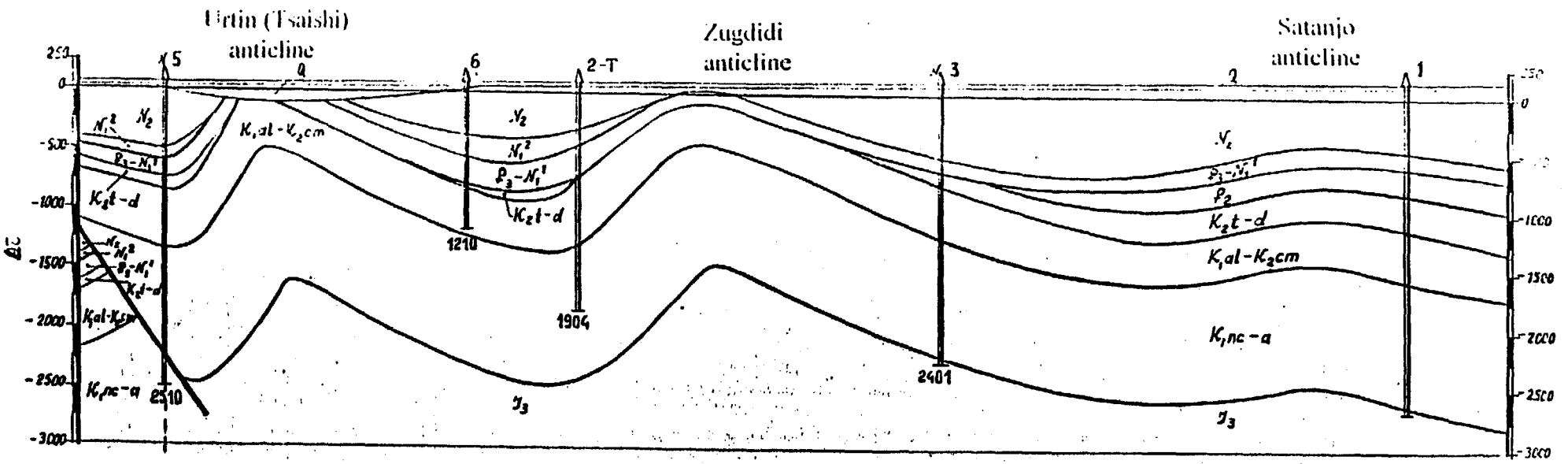
Legend

- contour line of roof of Apt-Neocomian depositions
- tectonic fracture
- existing wells
- line of geological section I - I


Geological Structural Map on Roof
of Apt-Neocomian Depositions
of the Zugdidi-Tsaishi Region
Zugdidi
Tsaishi
6-T
17-T
18-T
1-T
2-T
31-T
24-T
N3
9-T
12-T
10n
3-T
10-T
21-T
5-T
14-T
22-T
8-T
4-T
tectonic
fracture
0
500
1000
1500
2000
2500
3000
500
1000m
Legend
N1
- existing wells
line of roof of Apt-Neocomian depositions

Geological Section along Line I - I

Scale 1:50000

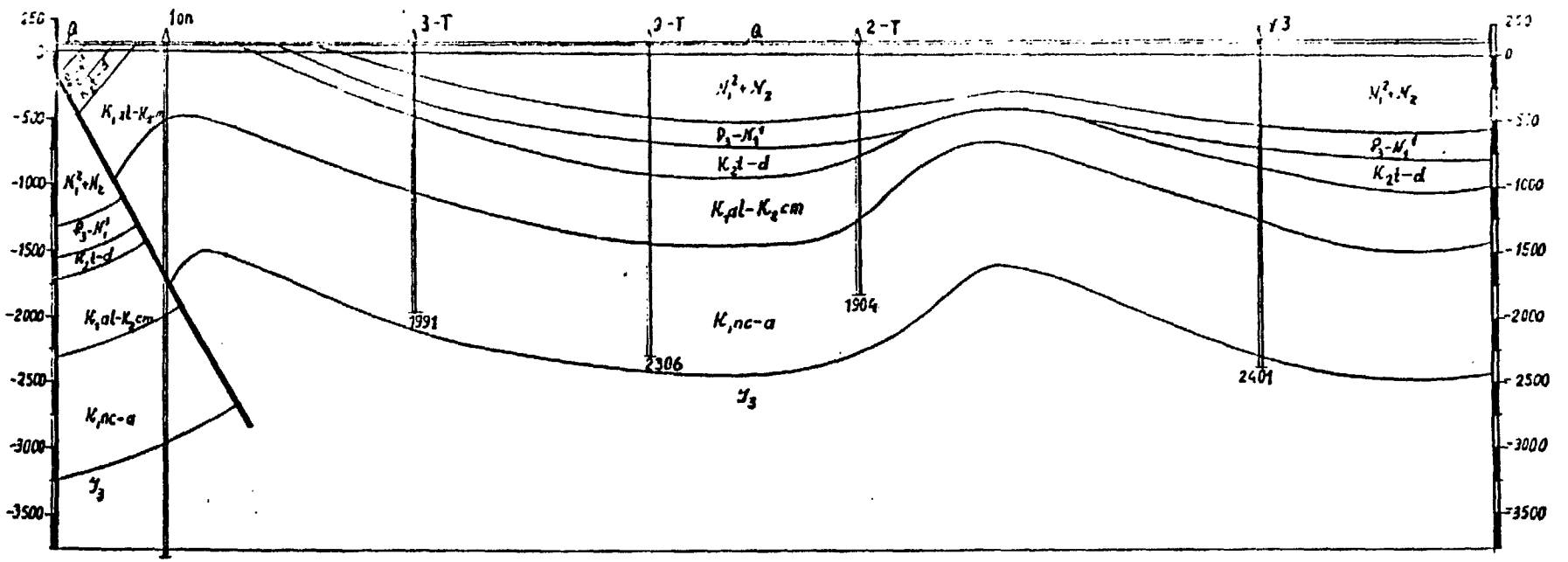


Legend

Q - Quarternary depositions	K_1al-K_2cm - Alb-Senomanian stage
$N_1^2+N_2$ - Middle Miocene + Pliocene	K_1nc - a - Neocomian substage - Apt stage
$f_3-N_1^1$ - Oligocene - Lower Miocene	I_3 - Upper Jurrasic
$K_2t-\alpha$ - Turon-Datt stage	

Geological Section along Line II - II

Scale 1:50000



Legend

- Q - Quarternary depositions
- $N_1^2+N_2$ - Middle Miocene + Pliocene
- $f_3 - N_1^1$ - Oligocene - Lower Miocene
- $K_2t - \alpha$ - Turon-Datt stage
- K_1al-K_2cm - Alb-Senomanian stage
- $K_1nc - a$ - Neocomian substage - Apt stage
- I_3 - Upper Jurrasic

Final estimation of the reserves and total output of Zugdidi-Tsaishi deposits were not carried out. It is only known, that initial debits of all existing wells are approximately 40,000 m^3/day. However, summing up of the initial debits of the wells cannot serve as actual measure of the deposit output, as it is necessary to consider interrelation of the wells.

Another factor to be considered in estimation of capacity of the deposit is selection of the method of geothermal energy utilization.

First method is based on geothermal water utilization with its further discharge into the open water reservoirs. This method may cause active pollution of the environment and exhaustion of natural resources. The other method supposes reinjection of used thermal water back into the underground water bearing horizon.

It should be noted, that so far all attempts of practical usage of geothermal water of Zugdidi-Tsaishi deposit have been based on the first method. However, definite efforts to study potential of reinjection had been made with significant results.

First test pumping within Zugdidi-Tsaishi deposit was carried out on well No. 5-T. The river water was pumped into the well and maximum acceptance capacity of 3,900 m^3/day was reached at 40 atm pressure. During the other test pumping, the geothermal water with T=86 ^{0}C was taken from well No. 3 and during 15 days was pumped back into well No. 2-T in 1,200 m^3/day quantity with permanent pressure of 10 atm. During the third test geothermal water with T=80^{0}C was taken from wells No. 1-T and 2-T and during 23 days was pumped back into well No 3 at various pressures. Maximum acceptance capacity of well No. 3 of 3,700 m^3/day volume was reached at the pressure of 25 amp.

Short-term pumping was carried out on well No. 31-T and, as a result, the well received 2,950 m^3/day at 18 atm pressure.

Unfortunately, during the test pumping hydrodynamic observation of the remaining wells were not performed.

In addition, after 1991 the works to preserve the wells in Zugdidi-Tsaishi region had not been carried out and water spillage out of some wells was uncontrollable. At present there is no updated information available on actual state of reserves of the deposit. However, considering the fact that during last five years majority of the wells had been closed, it could be concluded that the reserves of the deposit won't be significantly affected, even with uncontrolled leakage.

MAIN PARAMETERS OF WELLS OF THE ZUGDIDI-TSAISHI DEPOSIT

N N	NN of well	Start of operation	Altitude, m	water bearing interval, index	Depth, m	Pressure, atm	Debit, m^3/day	Temperature, ^0C	Formula of Chemical content	Function of well
1	2	3	4	5	6	7	8	9	10	11
1	1-OP	1963	34,3	731-1790, K_1	3728	0,30	1700	82	$M_{1,47}\frac{SO_4 64 Cl 26 HCO_3 10}{Ca 58 Na 19 Mg 19 K 4}$	Productive
2	1-T	1980	53,0	780-1272, K_1	1272	0,30	3800	86	$M_{1,18}\frac{SO_4 61 Cl 25 HCO_3 14}{Ca 58 Na 21 Mg 18 K 3}$	Productive
3	2-T	1980	58,62	1388-1904, K_1	1904	0,35	2800	87	$M_{1,24}\frac{SO_4 63 Cl 22 HCO_3 15}{Ca 55 Na 21 Mg 20 K 4}$	Productive
4	3-T	1982	71,0	1098-1900, K_1	1991	0,10	580	81	$M_{1,0}\frac{SO_4 60 Cl 23 HCO_3 17}{Ca 61 Na 20 Mg 19}$	Observation
5	4-T	1982	61,0	2100-2500, K_1	2527	-	-	-		Observation
6	5-T	1982	72,67	1190-1620, K_1	2661	0,18	1500	83	$M_{1,5}\frac{SO_4 73 Cl 20}{Ca 60 (Na+K) 26}$	Observation
7	8-T	1983	35,13	730-1675, K_1	1675	-	6000	84	$M_{1,54}\frac{SO_4 63 Cl 27 HCO_3 10}{Ca 56 Na 22 Mg 18 K 4}$	Productive
8	9-T	1985	65,73	1400-2306, K_1	2306	0,8	3000	92	$M_{1,65}\frac{SO_4 75 Cl 16 HCO_3 9}{Ca 61 Na 20 Mg 16 K 3}$	Reinjection
9	10-T	1985	35,81	2450-2800, K_1	2803	0,52	3000	102	$M_{2,4}\frac{Cl 50 SO_4 43 HCO_3 7}{Na 45 Ca 39 Mg 12 K 4}$	Productive
10	12-T	1986	62,69	1460-2410, K_1	2410	-	3000	90	$M_{1,59}\frac{SO_4 64 Cl 28 HCO_3 8}{Ca 55 Na 21 Mg 20 K 4}$	Reinjection

11	14-T	1986	32,0	1240-2000, K_1	2000	-	2500	84	$M_{1,42}\frac{SO_4 70 Cl 20 HCO_3 10}{Ca 67 Mg 19 Na 14}$	Reinjection
12	17-T	1987	44,8	2350-2749, K_1	2749	-	3000	96	$M_{1,19}\frac{SO_4 70 Cl 16 HCO_3 14}{Ca 55 Mg 23 Na 18 K 4}$	Reinjection
13	N3	1966	93,7	1525-2400, K_1	2401	0,17	3000	84	$M_{0,87}\frac{SO_4 61 Cl 21 HCO_3 18}{Ca 54 Na 25 Mg 21}$	Productive
14	18-T	1988	50,0	1584-2820, K_1	2820	-	2500	93	$M_{1,3}\frac{SO_4 68 Cl 20 HCO_3 12}{Ca 65 Mg 20 Na 15}$	Reinjection
15	21-T	1989	65,0	2300, K_1	2300	2,2	2200	88	$M_{1,45}\frac{SO_4 69 Cl 19 HCO_3 12}{Ca 53 Na 25 Mg 22}$	Reinjection
16	22-T	1990	64,8	K_1	2621	-	2500	89	$M_{1,5}\frac{SO_4 70 Cl 17 HCO_3 13}{Ca 50 Na 28 Mg 19}$	Reinjection
17	**24-T**	**1990**	**86,0**	**K_1**	**2100**	**-**	**-**	**-**	**-**	**Reinjection**
18	**31-T**	**1991**	**88.0**	**K_1**	**2615**	**-**	**-**	**-**	**-**	**Reinjection**

Note: Results of visual inspection in November, 1996

Well 1-OP
- -locking accessories of head part need to be repaired
- -geothermal water is used by population with no authorization
- -Building of pump station is located near the well, and its equipment is missing
- -Power supply line and transformer substation are damaged

Well 1-T
- - locking accessories of head part need to be replaced
- -Well hole is damaged and water self-flow is swamping surrounding territory
- - Building of pump station with damaged pump and metal tank of 50 m^3 volume are located near the well.
- - Power supply line and transformer substation are damaged

Well 2-T	- locking accessories of head part need to be replaced
	-Building of pump station is located near the well, and its equipment is missing
	- Power supply line and transformer station are damaged
	-geothermal water is used for heat supply to the chicken farm with no authorization
Well 3-T	- locking accessories of head part are missing
	-if nessessary well can be used as reinjection or observation one
Well 4-T	- locking accessories of head part need to be replaced
	-water level in well is stabilized on the 19-22 m depth
Well 5-T	- locking accessories of head part need to be replaced
	- currently there is no self-flow in this well
Well 8-T	- locking accessories of head part need to be replaced
Well 9-T	- locking accessories of head part are in working order
Well 10-T	- locking accessories of head part need to be replaced
	- pipeline is installed from this well, ∅=400 mm, length-4000 m to reinjection wells: 9-T, 12-T, 21-T, 22-T
Well 12-T	- locking accessories of head part need to be replaced
	- pipeline is installed from this well, ∅=150-300 mm to chicken farm under construction
Well 14-T	- locking accessories of head part are in working order
Wells 17-T, 18-T	- locking accessories of head part need to be replaced
	- geothermal water self-flow is swamping surrounding territory
Wells 21-T, 22-T	- locking accessories of head part need to be replaced
Well 31-T	- water level in the well is stabilized on the 19 m depth
Well 3	- locking accessories of head part need to be replaced
	- currently no self-flow is observed on this well
	- building of pump station is located near the well, and its equipment is missing
	- Power supply line and transformer substation is damaged

Aggressive Properties of Geothermal Water of the Zugdidi-Tsaishi Deposit

Studies of corrosion harshness of Zugdidi-Tsaishi deposit geothermal waters are limited by observations of the state of the piping which carry geothermal water from wells No. 3, 1-T and 4-T. These studies, which took place for 1 and a half years, determined that metal piping corrosion rate (metal type CT-3 according to the former USSR standards) was 1.13-1.15 mm/annually. This value exceeds acceptable rate of corrosion 25-30 times (0.04-0.05 mm/annually by USSR standards).

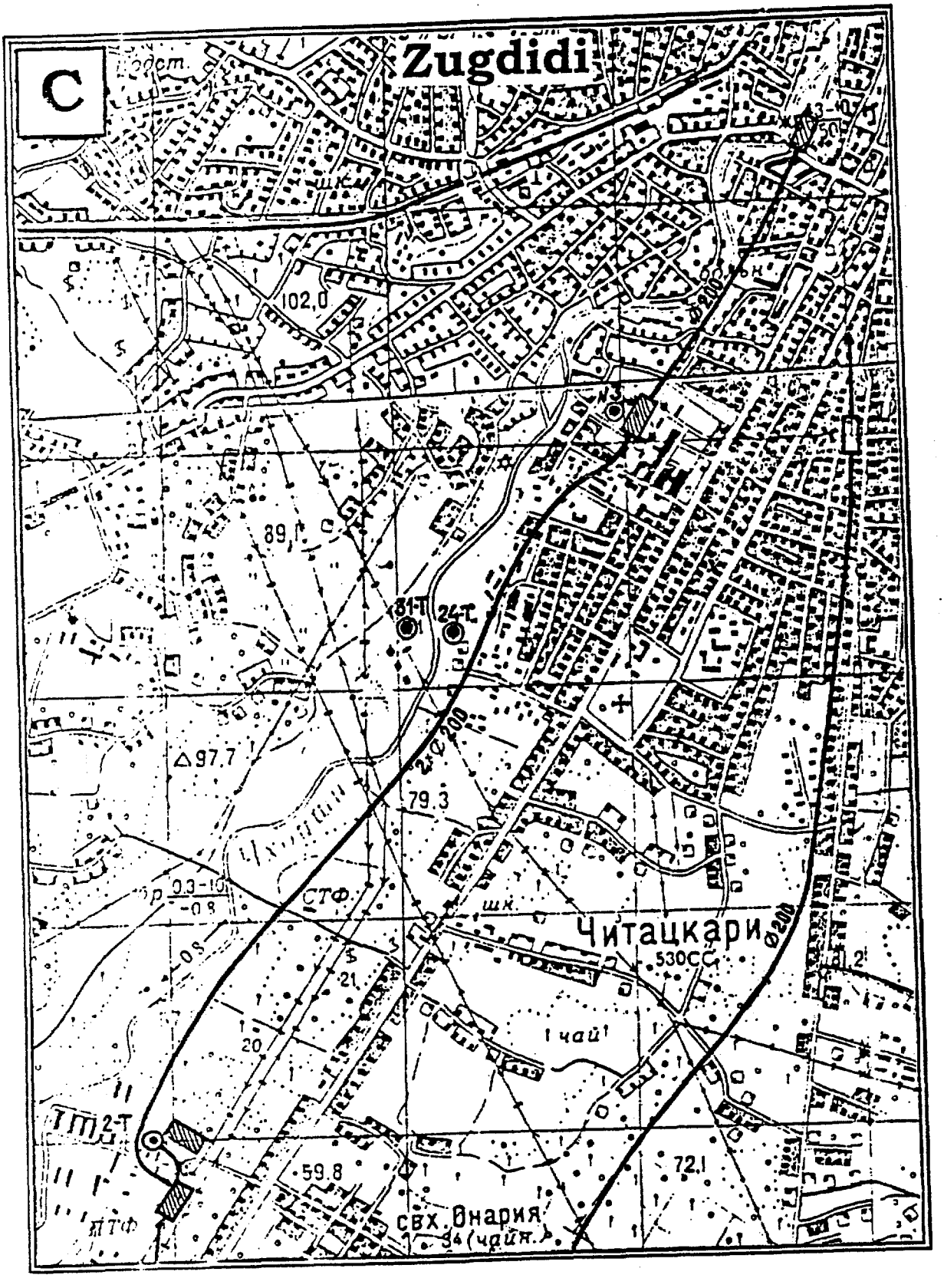
Except corrosion harshness, geothermal waters of Zugdidi-Tsaishi deposits tend to generate thick salty depositions, mainly those of carbonate calcium, on internal metal surfaces of the piping and equipment. Most intensified process of salt sedimentation takes place after geothermal water comes into contact with air. Salt sedimentation rate is not studied specifically.

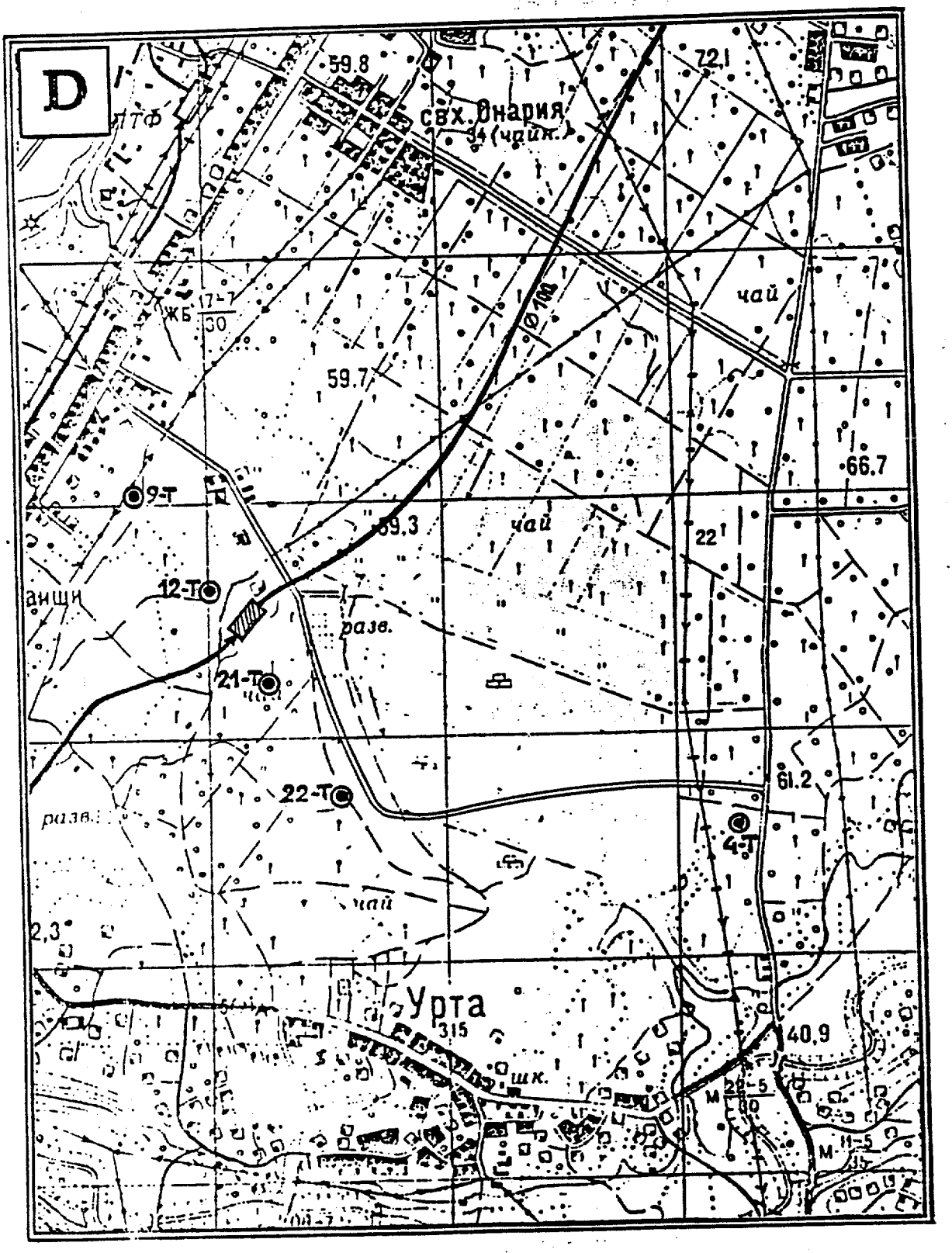
In practice of Zugdidi-Tsaishi deposit operation no methods had been used to neutralize or reduce aggressive qualities of geothermal waters.

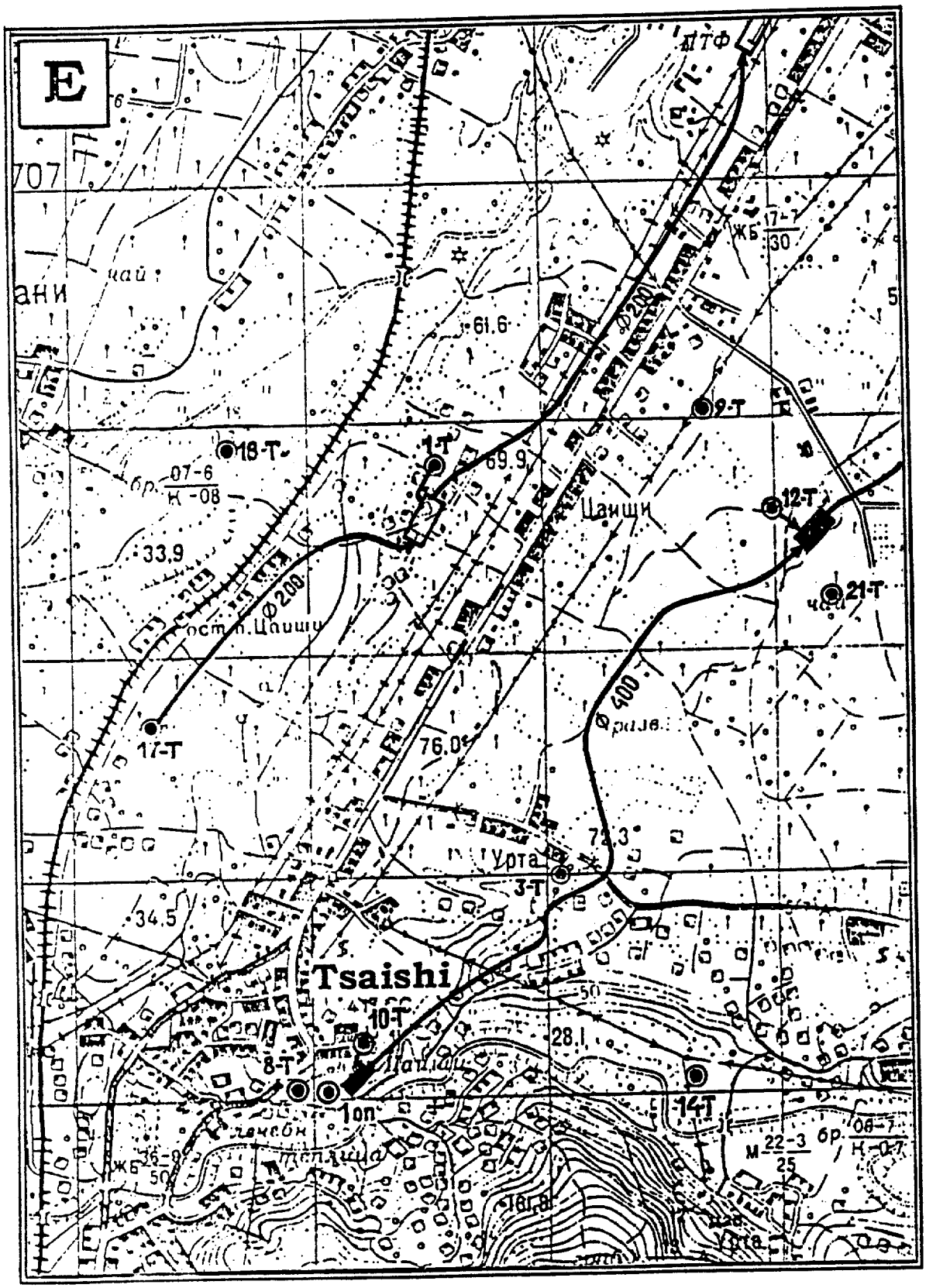
Review of Practical Utilization of Geothermal Water of the Zugdidi-Tsaishi Deposit

First experience of utilization of deposit is related with use of geothermal water extracted from well No. 3 for heating of the central part of city Zugdidi. For this very purpose there were built two pumping stations in Zugdidi in 1967-1968, one - directly at well No. 3 and the other in the central part of the city. The pumping stations were linked with each other by piping with 200mm diameter and 1,500 m length. The second pumping station supplied geothermal water to the existing centralized system of heating (there was no centralized hot water supply system in Zugdidi before). During the heating season (about 120 days annually) this system was capable to supply about 3,000 m^3/day of geothermal water and was designed to heat 45,000-50,000 m^2 residential and public buildings. However, actual efficiency of the heat supply system was rather low compared with its design values. This could be explained by the following basic reasons:

- low quality of thermal insulation of the piping caused significant loss of thermal energy;
- geothermal water was supplied to the customers without any prior treatment which resulted in presence of spontaneous gas which created air plugs in the heat supply systems;
- untreated geothermal water caused active salt deposition and corrosion in the piping;
- availability of two pumping stations in the heat supply system caused unexplained overcharge of electric power.


C
Zugdidi
102,0
89,1
31-Т
24-Т
97,7
79,3
СТФ
шк.
Читацкари
530СС
чай
59,8
72,1
свх. Онария
34 (чайн.)
ПТФ
2-Т


D
59.8
свх. Онария
54 (чайн.)
72.1
ЛТФ
ЖБ
17-7
30
чай
59.7
66.7
9-Т
69.3
чай
22
12-Т
разв.
21-Т
22-Т
61.2
4-Т
разв.
чай
2,3
Урта
315
40.9
шк.
М 29-5
М 11-5


E
Tsaishi
Цаишн
18-T
1-T
9-T
12-T
21-T
17-T
3-T
10-T
8-T
1оп
14-T
61.6
69.9
33.9
76.0
72.3
34.5
28.1
Урта
Ø200
Ø400

Despite the mentioned shortcomings, the system was operating till 1980 according to the described scheme. In 1980 well No. 2-T was drilled and this caused sharp reduction of debit in well No. 3. Instead of stopping the operation of the new well No 2-T and rehabilitation of initial debit of well No 3, additional pumping station at well No 2-T was built and piping of 5 km length was being laid up to well No 3. Later one more pumping station was built at well No. 1-T which was connected by the piping with the pumping station at well No. 2-T. Therefore, by 1987 total length of piping of the geothermal water supply system in Zugdidi exceeded 10 km and the designed capacity reached 5,000 m^3/day. As a result, the system of hot water supply became more and more expensive and energy consumption increased and effects of its initial shortcomings (low quality of thermal insulation and absence of measures to decrease aggressive ptoperties of geothermal water) were growing.

By 1988 operation of the this large system, which required 20 years to create, become senseless, as aggressive properties of geothermal water completely damaged the piping and radiators in the heated buildings in Zugdidi.

In 1986 when it became clear that the first geothermal system of hot water supply in Zugdidi would stop the operation, new attempts were undertaken to utilize thermal enery of the deposit. For this very reason a pumping station was built at well No. 12-T which is connected with the Municipal Hospital by the piping of 100mm (?!) diameter and more than 6 km length.

Two years later at the net of wells No. 1-OP, 8-T, 10-T one more pumping station was built which was supposed to be connected with the pumping station at well No. 12-T by the piping of 400mm diameter and 4,5km length, but the laying of the piping was not finished.

One more short glimpse in the history of deposit development is the experience of well No. 4-T utilization for heating and technological needs of Zugdidi Paper Plant. After three years of successful operation self-flow from well No. 4-T has ceased which was connected with exploration of new wells in Tsaishi region.

Therefore, to sum up the review of the practical experience of utilization of the Zugdidi-Tsaishi geothermal water deposit we can conclude:

- development of the deposit was rather spontaneous;
- drilling of new wells, as a rule, was never connected with optimization of already existing systems of heat supply and in the rest of the cases even disturbed the operation of existing system;
- the problems of environmental protection had been completely ignored;
- history of the deposit development counts numerous cases of violation of the simplest rules of design and construction of the system of heat supply.

Design Solutions on Optimisation of Operation of the Zugdidi-Tsaishi Geothermal Deposit

Currently there is no any regular operation of the Zugdidi-Tsaishi geothermal deposit. All buildings and communications of existing heat-supply systems are deteriorated: lock valves on head-parts of wells are out of order; most thermal pipelines are missing; buildings of pumping stations are half-destroyed or used for other purposes; equipment is dismounted. Therefore, the single parts of the system that still have any value are existing wells, but their actual condition needs to be specially studied.

Notwithstanding all this local authorities of Zugdidi and potential consumers express great interest in quick rehabilitation of geothermal heat supply system. But it should be noted. that their requirements are related only with provision of heating and there are no requests on use of thermal energy for industrial purposes.

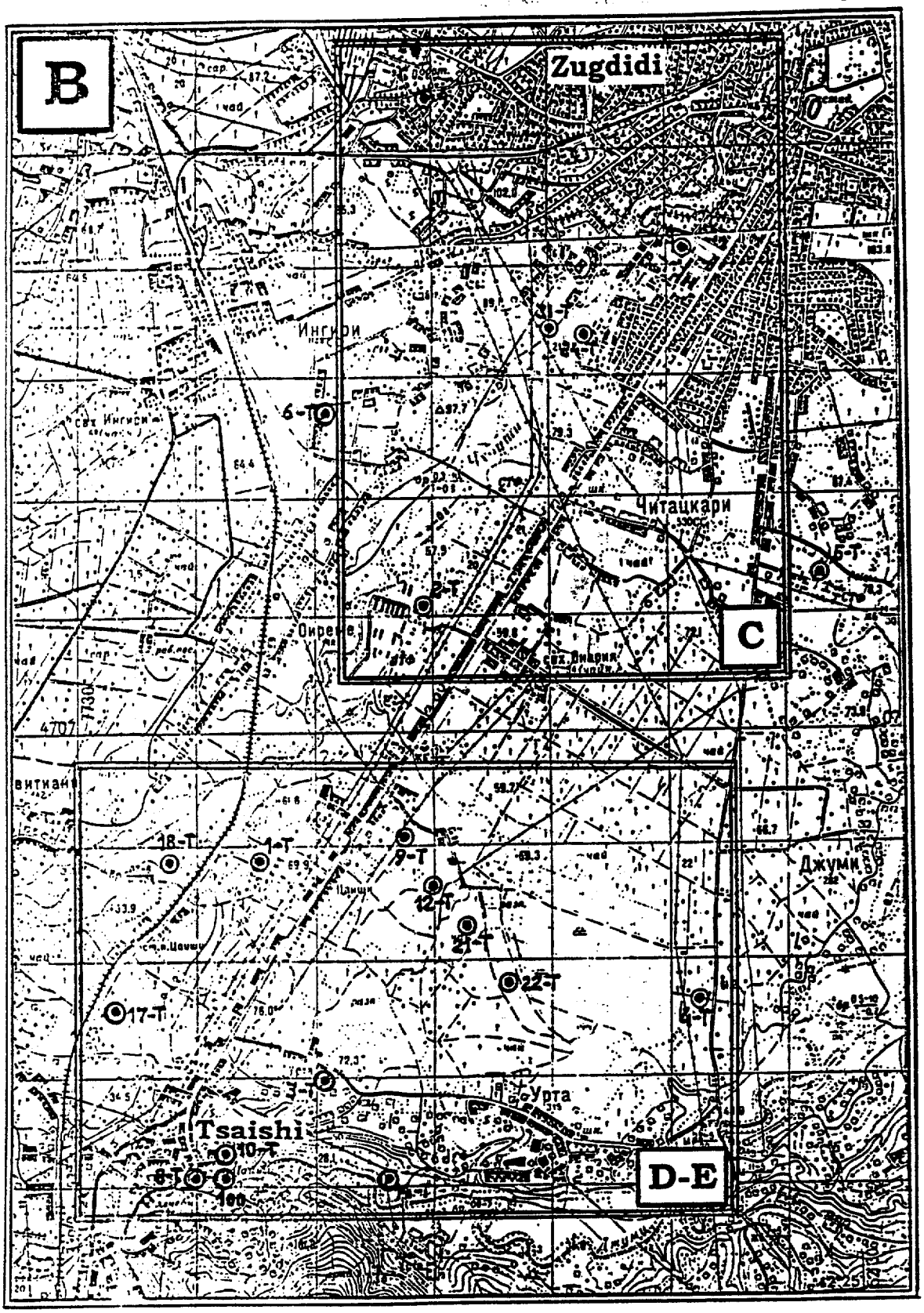
Due to lack of any reasonable long-term programm of effective utilization of geothermal deposit potential the study presented here developed design solutions, which are based on the following main principles:

- provision of maximal utilization of geothermal potential of existing wells and refusal from drilling of new wells on the first stage of rehabilitation.
- utilization of wells located on minimal distance from existing and potential consumers initially.
- inclusion of reinjection of discharged geothermal water to keep reserve of deposit and avoid pollution of environment.
- inclusion of preliminary treatment of geothermal water in order to reduce active corrosion and salt deposition in primary (geothermal) loop.
- exclusion of danger of corrosion and salt deposition in the consumers'heat supply systems by construction of secondary loop with fresh water.
- provision of recommendations on creation of new consumers, in case if existing consumers will not be able to utilize fully the supplied thermal energy.

Analysis of interlocation of existing wells and their productivity allowed to divide (conventionally) the territory of the deposit into three areas:

- Zugdidi area (see map C);
- Tsaishi area (see map D);
- Western Tsaishi area (see map E).

The wells located on territories of each area can provide supply of definite amount of geothermal water and provide reinjection of discharged geothermal water as well. This will allow to create the local system of geothermal heat supply in each area.


B
Zugdidi
Ингури
6-T
Читацкари
C
Окрепе
витиан
18-T
1-T
9-T
12-T
21-T
22-T
17-T
Джуми
Урта
Tsaishi
10-T
D-E

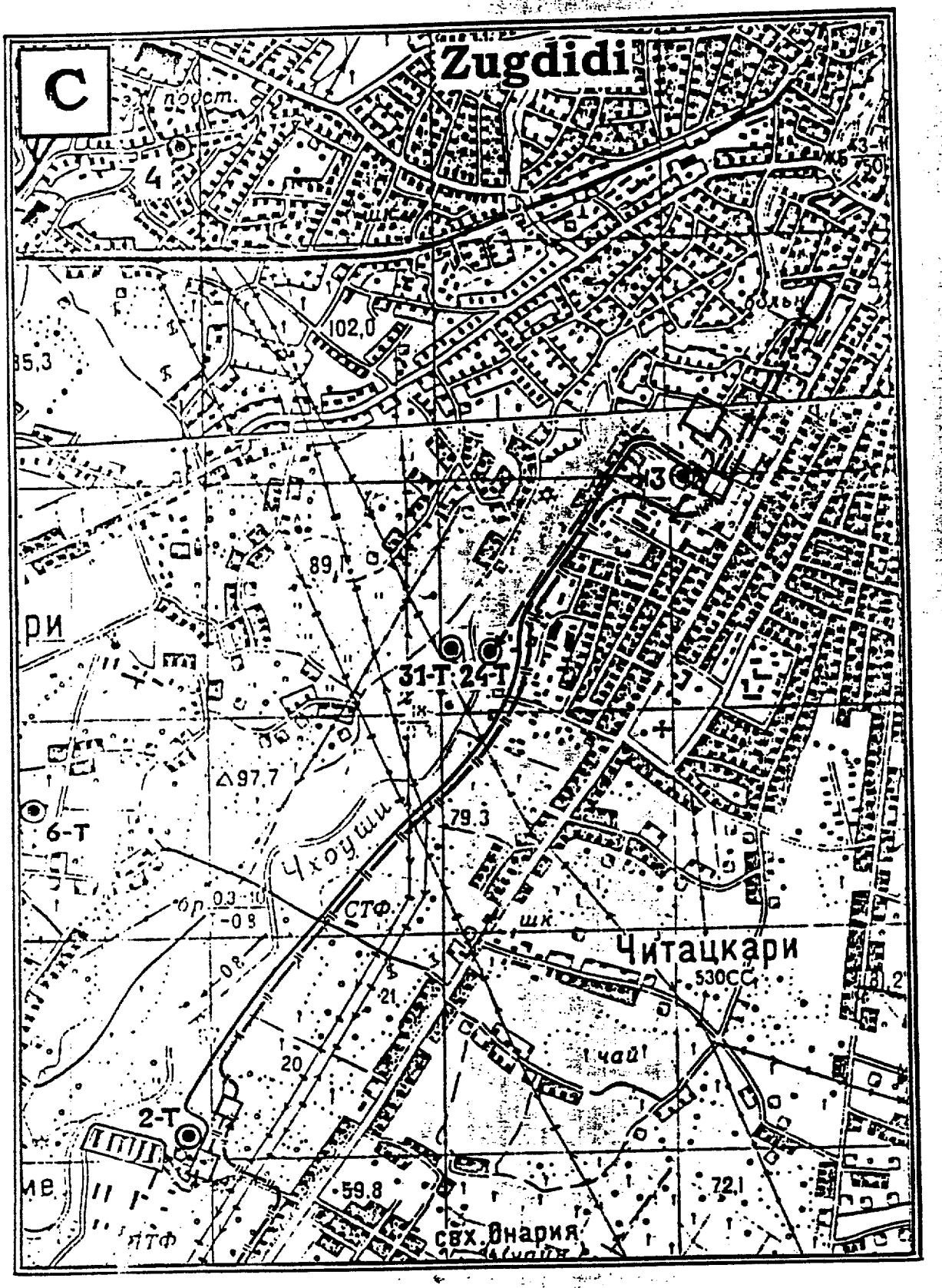
Design Proposal on Construction of the Zugdidi Geothermal Heat Supply System (Zugdidi Area)

Principal Scheme

Design proposal given below describes possibility of utilization of geothermal potential of wells No. 2-T and No. 3 for construction of the Geothermal Heating Station, which will have enough capacity to supply heat to consumers in the central part of town Zugdidi.

Design proposal envisages:

- obtaining geothermal water from productive wells No. 2-T and No. 3 in self-flow regime.
- preliminary treatment of geothermal water obtained from well No. 2-T with use of vacuum degasator.
- utilization of steam obtained as a result of vacuum degasation for heating of heat-carrier in the system of heat supply of existing poultry farm, situated in close vicinity of well No. 2-T (such cycle of heat supply to poultry farm is proposed for cold period of year, but during the rest of the year degased geothermal water is proposed for heat supply of poultry farm).
- transportation of degased geothermal water with use of pumps on the distance of 5 km by thermo-insulated pipeline up to the Geothermal Heating Station, located in vicinity of well No. 3 (in construction of pipeline it's possible to use preserved sections of existing geothermal pipeline with total length up to 2.5 km).
- thermal energy exchange between geothermal water from the wells No. 2-T and No. 3 and fresh water in secondary loop with use of plate-type heat-exchangers installed in the Geothermal Heating Station (existing building used before as pumping station will be used for installation of equipment of the Geothermal Heating Station).
- collection of cooled (used) geothermal water into tank with its further pumping (reinjection) in wells No. 24-T and No. 31-T.
- pumping out of cold fresh water from existing artesian wells located in the vicinity of well No. 2-T and its transportation by pipeline to the Geothermal Heating Station (this is included due to shortage of fresh water in Zugdidi).
- utilization of fresh water treated with use of sodium-cationite filters for filling and adding to secondary loop of heat supply system.
- provision of circulation of heat carrier (fresh water) in secondary loop of heat supply system.
- use of heat exchangers for group of consumers of hot water supply.


C
Zugdidi
102,0
89,1
31-Т
24-Т
43
97,7
6-Т
79,3
Чхоуши
СТФ
шк.
Читацкари
530СС
21
20
чай
2-Т
59.8
72,1
свх.Онария
ятф

Consumers

Population of Zugdidi equals 50 thousand, 80% of which dwells in private houses with land lots. Density of houses with lots is very low and due to this prospects of use of centralized heat supply system in this part of town look rather unreasonable. Besides, this type of dwelling houses are not equiped with systems of water heating as a rule.

Central part of town is built by multistore houses, inhabited by approximately 20% of town's population. Namely this part of population, as well as municipal, communal and industrial buildings located in the town center, can become consumers of Zugdidi geothermal heat supply system. It should be noted that existing heat distribution network and heat supply systems in the buildings are heavily damaged during previous years by aggressive geothermal water. Due to this most pipelines and radiators of heat need replacement. As concerns the centralized hot water supply it's absent even in multistore residential buildings.

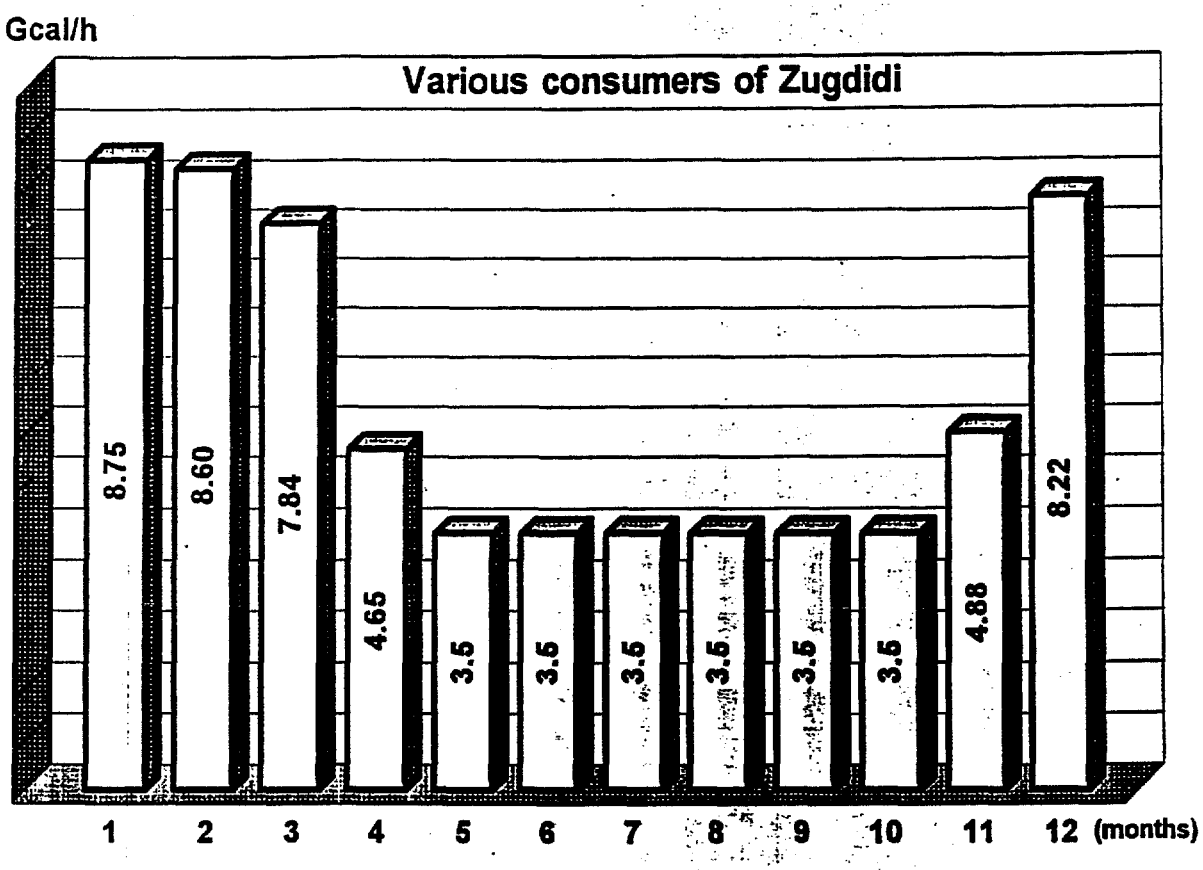
But even in these conditions taking into consideration low cost of used thermal energy supply of geothermal heat to the central part of Zugdidi should be considered as optimal solution of the heat supply problem.

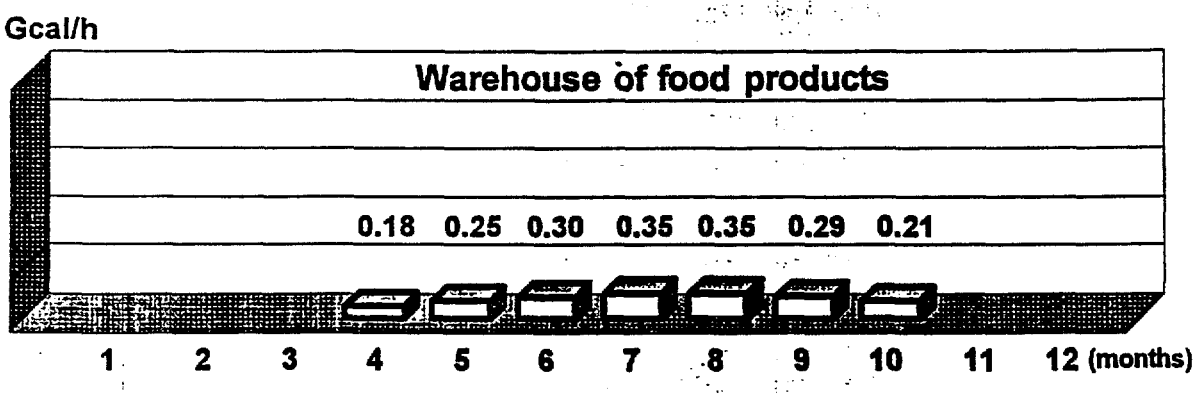
In order to increase efficiency of proposed geothermal system of heat supply it's recommended to construct new facility in the central part of the town, operation of which will allow to smooth partially seasonal irregularities of thermal energy consumption. This kind of facility might be vegetable store, which can be suitable placed on the territory adjacent to existing agricultural market. Another permanent consumer of Zugdidi geothermal heat supply might become existing poultry farm located in close vicinity of the well No. 2-T.

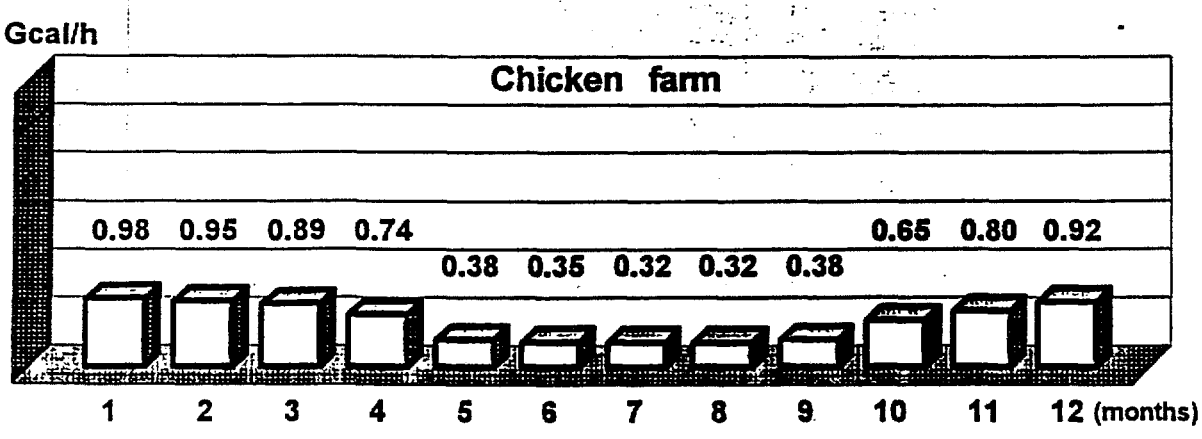
Therefore, proposed system of geothermal heat supply for Zugdidi area will be able to serve the following consumers:

1. Heating of residential, municipal, communal and industrial buildings located in the central part of Zugdidi with total space - 100000 m^2.
2. Hot water supply to population of central part of the town and also to population living on the territory located along the thermal pipeline (number of dwellers on section from the Geothermal Heating Station to town center - 10000 - 12000)
3. Vegetable store with capacity 200 tonnes.
4. Poultry farm with productivity 120 tonnes/year.

Chart of hourly consumption of thermal energy by various consumers of the Zugdidi geothermal system of heat supply versus months of the year.







Summary chart of hourly consumption of thermal energy by all consumers of the Zugdidi geothermal system of heat supply versus months of the year.

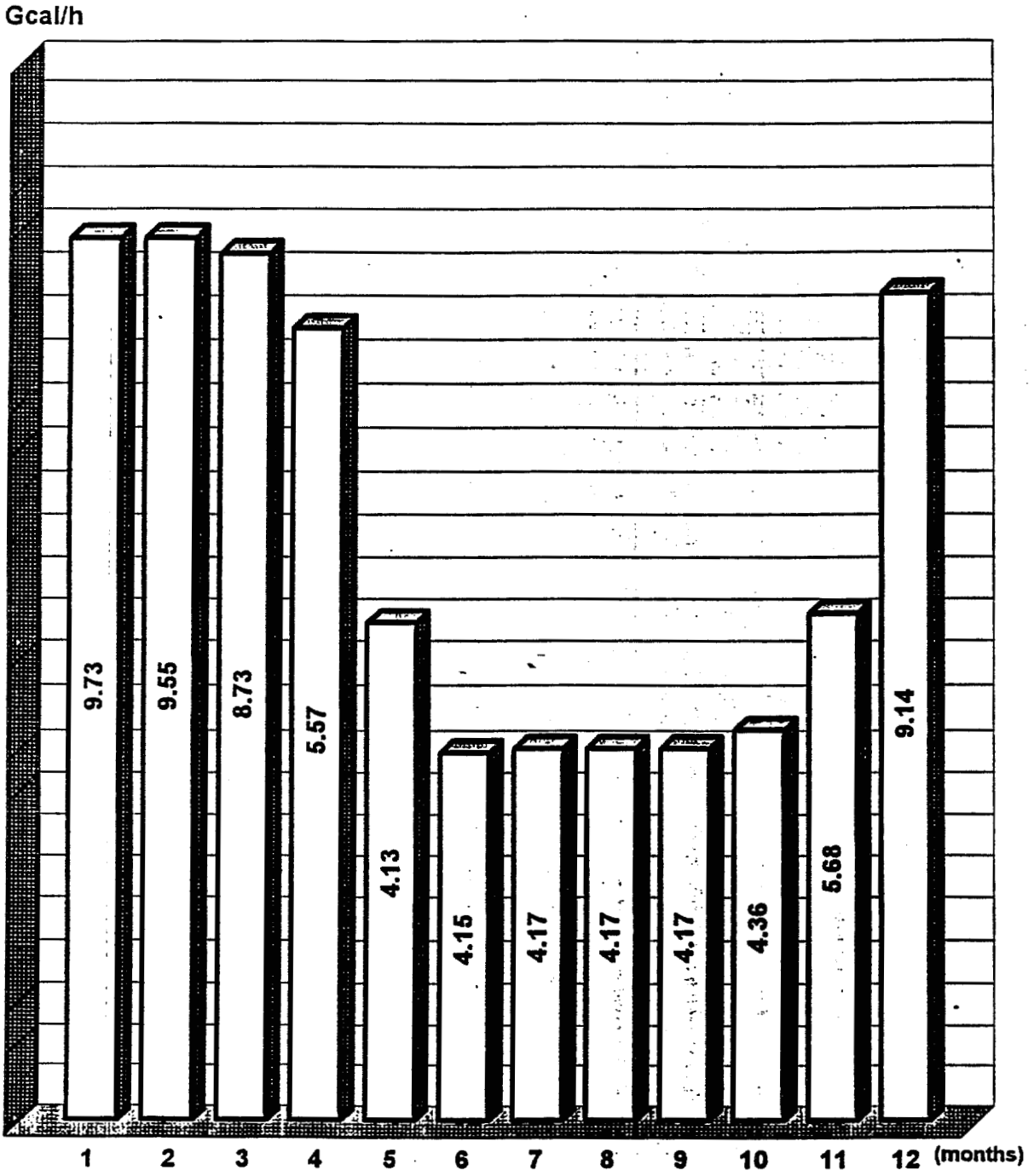


Table No. Z-1

Demand of thermal energy by the consumers of the Zugdidi geothermal heat supply systems

	Consumers	Purpose of thermal energy	Unit of measure	Months											
				I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	Average monthly temperature of ambient air		^{0}C	4,9	5,5	8,2	12,3	17,0	20,3	22,6	22,7	19,2	15,1	10,5	6,7
1.	Various consumers of Zugdidi	Heating	Gcal/h	5,25	5,10	4,34	1,15	-	-	-	-	-	-	1,38	4,72
		Hot water supply	Gcal/h	3,50	3,50	3,50	3,50	3,50	3,50	3,50	3,50	3,50	3,50	3,50	3,50
2.	Warehouse of food products	Cooling	Gcal/h	-	-	-	0,18	0,25	0,30	0,35	0,35	0,29	0,21	-	-
3.	Chicken farm	Heating	Gcal/h	0,90	0,87	0,81	0,66	0,30	0,27	0,24	0,24	0,30	0,57	0,72	0,84
		Hot water supply	Gcal/h	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08
	Total consumption		Gcal/h	9,73	9,55	8,73	5,57	4,13	4,15	4,17	4,17	4,17	4,36	5,68	9,14
	Duration of month		hour	744	678	744	720	744	720	720	744	720	744	720	744
	Total average monthly consumption		Gcal	7239	6439	6495	4010	3072	2988	3002	3102	3002	3244	4090	6800
Total annual consumption of thermal energy			Gcal	53 520											

Table No. Z-2

Parameters of heat carrier in primary (geothermal) loop of the Zugdidi geothermal heat supply system

Parameters of heat carrier	Unit of measure	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Amount of geothermal water from well No. 3	m^3/h	125	125	125	112	75	76	77	77	76	75	116	125
Temperature of geothermal water from well No. 3 at the inlet of heat exchanger	^0C	95	95	95	95	95	95	95	95	95	95	95	95
Amount of geothermal water from well No.2-T	m^3/h	120	114	89	24	12	11	10	10	12	21	26	94
Temperature of geothermal water from well No. 2-T at the inlet of heat exchanger	^0C	75	75	75	-	-	-	-	-	-	-	-	75
Temperature of geothermal water discharged from well No. 2-T to the tank of cooled water	^0C	-	-	-53	53	53	53	53	53	53	53	53	-
Amount of pumped geothermal water	m^3/h	245	239	214	136	87	87	87	87	88	96	142	219
Temperature of mixture of used heat carrier	^0C	48,9	49,0	49,5	51,5	46,1	46,1	46,1	46,1	46,1	46,1	48,6	49,6

Table No. Z-3

Use of heat carrier in secondary loop of the Zugdidi geothermal heat supply systems

	Consumers	Purpose of heat carrier	Potential of heat carrier	Unit of measure	Months											
					I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	Average monthly temperature of ambient air			^0C	4,9	5,5	8,2	12,3	17,0	20,3	22,6	22,7	19,2	15,1	10,5	6,7
1.	Various consumers of Zugdidi	Heating	80^0C-50^0C	m^3/hr	175	169	144	38	-	-	-	-	-	-	46	149
		Hot water supply	80^0C-30^0C	m^3/h	70	70	70	70	70	70	70	70	70	70	70	70
2	Warehouse of food products	Cooling	80^0C-30^0C	m^3/h	-	-	-	4	5	6	7	7	6	5	-	-
3.	Chicken farm	Heating	80^0C-50^0C	m^3/h	30	29	27	22	10	9	8	8	10	19	24	28
		Hot water supply	80^0C-30^0C	m^3/h	2	2	2	2	2	2	2	2	2	2	2	2
	Amount of used heat carrier		50^0C	m^3/h	175	169	144	38	-	-	-	-	-	-	46	149
			30^0C	m^3/h	70	70	70	74	75	76	77	77	76	75	70	70
	Mixture temperature of used heat carrier			^0C	43,7	43,5	42,8	36,2	30,0	30,0	30,0	30,0	30,-	30,0	37,3	43,2

Table No. Z-4

Electric power consumption in primary loop (on transportation and reinjection of geothermal water) of the Zugdidi geothermal heat supply system

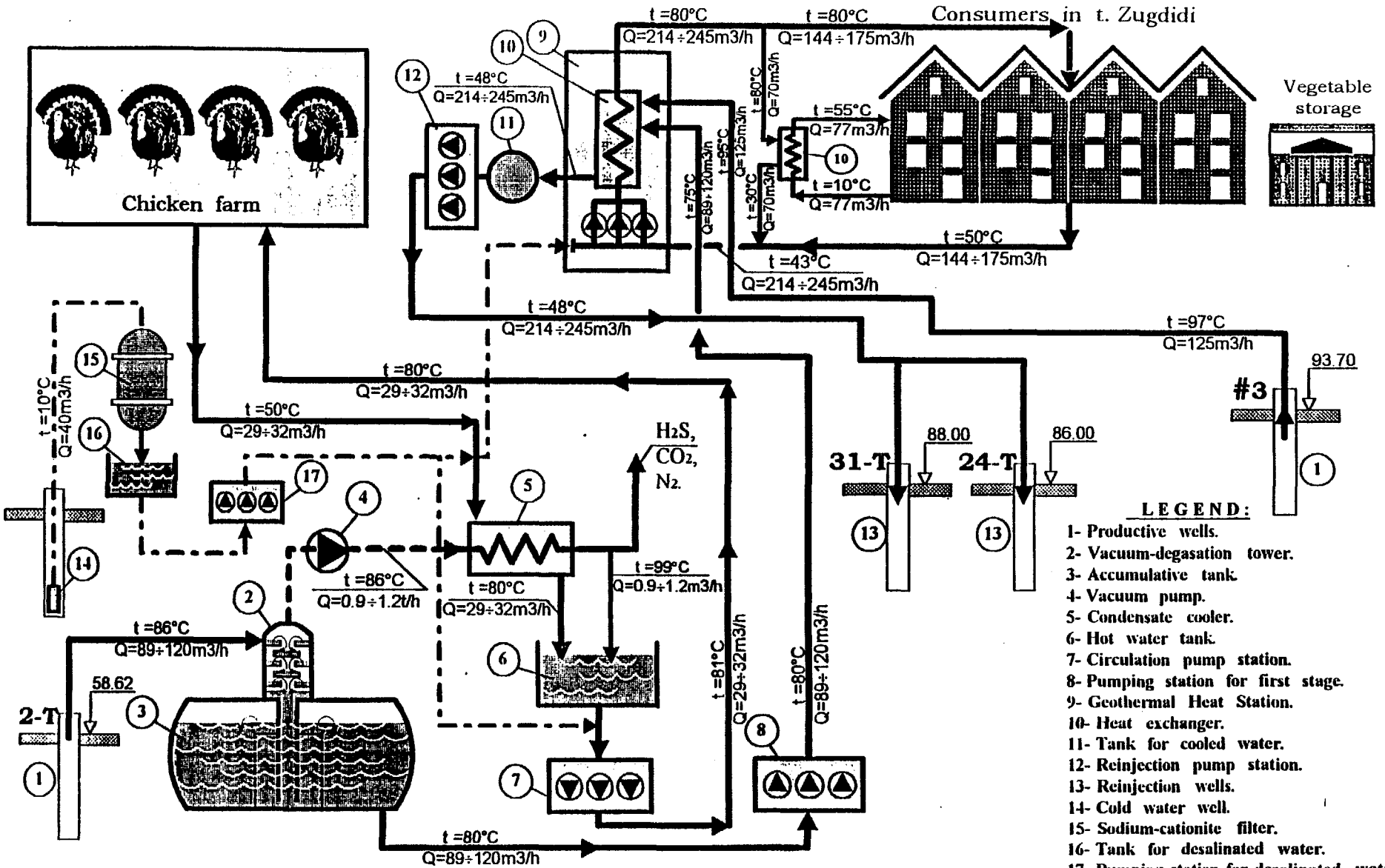
Design parameters	Unit of measure	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Amount of geothermal water transported from well No. 2-T	m^3/h	120	114	89	24	12	11	10	10	12	21	26	94
Number of operating pumps of type TsNSG 180-85 used for transportation of geothermal water	item	1	1	1	-	-	-	-	-	-	-	-	1
Number of operating pumps of type K80-50-200 used for transportation of geothermal water	item	-	-	-	1	1	1	1	1	1	1	1	-
Total capacity of operating pumps	MW	0,055	0,055	0,055	0,055	0,055	0,055	0,055	0,055	0,055	0,055	0,055	0,055
Amount of geothermal water pumped into wells No. 24-T and 31-T	m^3/h	245	239	214	136	87	87	87	87	88	96	142	219
Number of operating pumps of type TsNSG106-196 used for reinjection of used water	item	2	2	2	2	1	1	1	1	1	1	2	2
Total capacity of operating pumps	MW	0,22	0,22	0,22	0,22	0,11	0,11	0,11	0,11	0,11	0,11	0,22	0,22
Duration of pumps operation	hour	744	678	744	720	744	720	720	744	720	744	720	744
Average monthly power consumption by operating pumps of primary loops	MW.h	204,6	186,5	204,6	169,2	93,0	90,0	90,0	93,0	90,0	93,0	169,2	204,6
Other consumption of electric power	MW.h	15,0	13,5	15,0	14,0	15,0	14,0	14,0	15,0	14,0	15,0	14,0	15,0
Total annual consumption of electric power	MW.h	1861,2											

Table No. Z-5

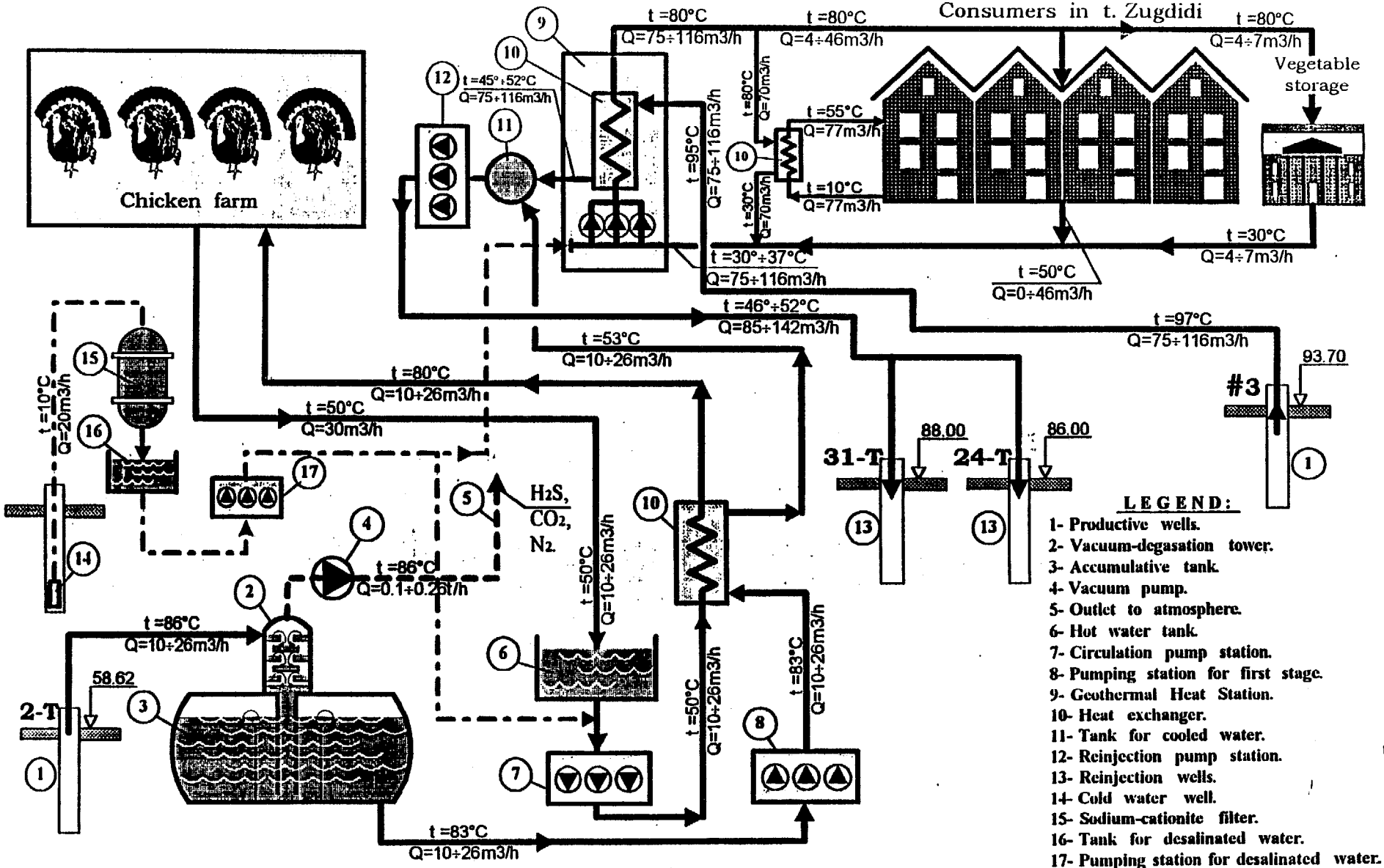
Electric power consumption for circulation of heat carrier in secondary loops of the Zugdidi geothermal heat supply system

Design parameters	Unit of measure	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Amount of heat carrier circulating in secondary loop of Zugdidi chicken farm	m^3/h	32	31	29	24	12	11	10	10	12	21	26	30
Number of operating pumps of type K80-50-200	item	1	1	1	1	1	1	1	1	1	1	1	1
Capacity of operating pumps	MW	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015
Amount of heat carrier circulating in secondary loop of town Zugdidi	m^3/h	245	239	214	112	75	76	77	77	76	75	116	219
Number of operating pumps of type TsNSG 60-99	item	3	3	3	2	1	1	1	1	1	1	2	3
Capacity of operating pumps	MW	0,09	0,09	0,09	0,06	0,03	0,03	0,03	0,03	0,03	0,03	0,06	0,04
Duration of pumps operation	hour	744	678	744	720	744	720	720	744	720	744	720	744
Average monthly power consumption by operating pumps of secondary loops	MW.h	78,1	71,2	78,1	54,0	33,5	32,4	32,4	33,5	32,4	33,5	54,0	78,1
Other consumption of electric power	MW.h	45,0	40,5	45,0	42,0	45,0	42,0	42,0	45,0	42,0	45,0	42,0	45,0
Total annual consumption of electric power	MW.h	1131,7											

Zugdidi Geothermal System of Heat Supply
Principal Scheme of System Operation in Cold Period of Year



Zugdidi Geothermal System of Heat Supply
Principal Scheme of System Operation in Warm Period of Year



LEGEND:

1- Productive wells.
2- Vacuum-degasation tower.
3- Accumulative tank.
4- Vacuum pump.
5- Outlet to atmosphere.
6- Hot water tank.
7- Circulation pump station.
8- Pumping station for first stage.
9- Geothermal Heat Station.
10- Heat exchanger.
11- Tank for cooled water.
12- Reinjection pump station.
13- Reinjection wells.
14- Cold water well.
15- Sodium-cationite filter.
16- Tank for desalinated water.
17- Pumping station for desalinated water.

Tentative Budget for Arrangement of Zugdidi Geothermal Heat Supply System

A. Development of primary (geothermal) loop of heat supply

Chapter 1. Rehabilitation and modification of system for extraction and treatment of geothermal water.

N.N	Item	Unit	Quantity	Price thousand $	
				per unit	total
1.1	Rehab. of head-part of existing productive wells No. 2-T and 3	items	2	5.0	10.0
1.2	Installation of collector-tank "DCA-100" of 50 m^3 volume	item	1	20.0	20.0
1.3	Installation of degassing tower DCB-150	item	1	10.0	10.0
1.4	Installation of vacuum-pump HB-3-100D	item	1	8,5	8,5
1.5	Installation of steam condenser OBA-16	item	1	5.0	5.0
1.6	Installation of thermoinsulated pipelines from productive well 2-T to the collector-tank	m	100	0,08	8.0
1.7	Rehab. of wells down to 50 m depth to receive cold filtrates	item	3	5.0	15.0
1.8	Outfitting of cold water wells with deep-water pumps ATH10-6	item	3	8.5	25,5
1.9	Installation of low-voltage power supply line and electric equipment				10.0
1.10	Rehab. of access roads and arrangement of territory around productive wells				18.0
	Total for Chapter 1				130.0

Chapter 2. Rehabilitation and Modification of Geothermal Water Transportation System

N.N	Item	Unit	Quantity	Price thousand $ per item	total
1	2	3	4	5	6
2.1	Rehab. and expansion of existing building of Pump Station at the chicken farm (well No. 2-T)	m^2	250	0.20	50.0
2.2	installation of pumps of type CNSG 105-98 for geothermal water	item	2	6.0	12.0
2.3	The same of type K80-50-200 (k45/550)	item	2	2.0	4.0
2.4	Installation of pumps 80-50-200 (k45/55) for circulation of heat carrier in the secondary loop of heat supply system of chicken farm	item	2	2.0	4.0
2.5	Installation of pumps of type KC 50-55, providing heat carrier replenishment in the secondary loop of heat carriers of chicken farm and city heating net system	item	3	4,5	13,5
2.6	Installation of water treatment equipment and Sodium-cationite filters	set	1	45,0	45,0
2.7	Installation of corrosion-resisting plate heat exchangers	set	2	15	30,0
2.8	Installation of pipelines on the territory of the pump station	m	100	0,06	6.0
2.9	Construction of ferroconcreat reservoir for fresh water of 300 m^3	item	1	30.0	30.0
2.10	Installation of electrical equipment for the pump station				15.0
2.11	Installation of high voltage power supply line	m	2500	0.01	25
2.12	Arrangement of transformer sub-station	set	1	30	30
2.13	Installation of low voltage power supply line	m	100	0.02	2.0
2.14	Installation of thermoinsulated water tank for the condensate of 15 m^3 volume	item	1	2,5	2.5
2.15	Arrangement of access road and territory of the pump station				20.0

2.16	Rehab. and thermoinsulation of existing pipeline from the well 2-T to geothermal power station	m	2500	0.016	40.0
2.17	Construction of missing section of pipeline to geothermal power station	m	2500	0,032	80.0
2.18	Installation of pipeline for treated water from pump station to geothermal power station	m	5000	0.02	100.0
	Total for Chapter 2				509.0

Chapter 3. Installation of Geothermal Power Station and System for Reinjection of Cooled (Discharge) Geothermal Water.

N.N	Item	Unit	Quantity	Price thousand $	
				per item	total
3.1	Construction of power station building	items	200	0.3	60.0
3.2	Installation of corrosion resident plate heat exchangers	set	9	15.0	135.0
3.3	Installation of reinjection pumps of type CNSG105-196	item	3	11.0	33.0
3.4	Installation of pump (type CNSG 60-99), providing circulation of heat carrier in secondary loop of city heat supply system	item	4	3.0	12.0
3.5	Construction of ferroconcrete reservoir for cooled geothermal water of 100 m^3	item	1	12.0	12.0
3.6	Installation of pipelines on the territory of power station	m	250	0.06	15.0
3.7	Installation of electrical equipment of power station				15.0
3.8	Rehab. of head part of existing reinjection wells No. 24-T and 31-T	item	2	5.0	10.0
3.9	Installation of pipelines from power station to reinjection wells	m	2000	0,036	72.0
3.10	Installation of high voltage power supply line	m	1500	0,01	15.0
3.11	Arrangement of transformer substation	set	1	40.0	40.0
3.12	Installation of low voltage power supply line	m	50	0,02	1.0
3.13	Arrangement of access road and of the territory of power station and reinjection wells				
3.14	Installation of I&C equipment and of the system of automation of technological process				180.0
	Total for Chapter 3				630

B. Installation of the secondary (freshwater) loop of heat supply system

Chapter 4. Installation of Distribution Net for Heat Supply of Consumers in Zugdidi

N.N	Item	Unit	Quantity	Price thousand $	
				per item	total
4.1	Construction of thermo-insulated pipeline of 300 mm diameter	m	3000	0.08	240.0
4.2	Construction of thermo-insulated pipeline of 200 mm diameter	m	3000	0.04	120.0
4.3	Construction of thermo-insulated pipeline of 150 mm diameter	m	4000	0.025	100.0
4.4	Construction of thermo-insulated pipeline of 100 mm diameter	m	5000	0.02	100.0
	Total for Chapter 4				560.0

Chapter 5. Expences on Connection to Existing Communications

N.N	Item	Unit	Quantity	Price thousand $	
				per item	total
5.1	Connection of pump station to existing water supply and sewage systems of Zugdidi chicken farm near the well 2-T	m	200	0.04	8.0
5.2	Connection of geothermal power station to the existing water supply and sewage systems of Zugdidi near well No. 3	m	300	0.05	15.0
5.3	Connection of the pump station and geothermal heating station to the existing communication lines				12.0
	Total Chapter 5				35.0

C. Other Expences

Chapter 6. Exploration and Design Works, Obtaining of Licenses for Using of Land Lots

N.N	Item	Unit	Quantity	Price thousand $ per item	total
6.1	Test pumping into reinjection wells No. 24-T and 31-T				50.0
6.2	Working out of detailed project of Zugdidi heat supply geothermal system	% of total for Chapters 1-5	8		145.0
6.3	Technical supervision and acceptance of executed works during the construction process	"	3		55.0
6.4	Obtaining of licenses on the land lots previously used in agriculture	hectare			600.0
	Total for Chapter 6		2.0	300.0	850.0

TOTAL FOR CHAPTERS 1-6 2 679

Note: Item 6.4 can be adjusted according to changes in Georgian legislation on landuse.

Annual expences needed for operation of the Zugdidi geothermal heat supply system

	Type of Expences	Total Annual, Thousand $
	I. Operational expences	
1.1	Expences on purchase of electric energy in amount of 2993 MW.hour at cost of 1 MW.hour - $ 36.0	107.7
1.2	Expences on purchase of other materials and services	50.0
1.3	Expences on current repairs of equipment, buildings and constructions in amount of 5% of summ of capital expences on construction of geothermal system (chapter 1 - chapter 5)	91.5
1.4	Expences on labor cost for personnel (15 persons), including payments for social insurance and medical insurance of personnel	63.0
	II. Depreciation charges	
2.1	Depreciation charges on condition of 25 year term of operation of geothermal system	73.2
	Total	385.5

Cost of thermal energy

At selling of thermal energy in amount of 53520 Gcal per year and with annual operational expences in amount of $ 385500 US dollars

Cost of 1 Gcal = $ 7.2

Economic effectivity of investments

I option - At tariff on 1 Gcal equal to $ 15.0 net profit from selling of 1 Gcal (after payment of all taxes and payments for licenses) will amount approximately $ 4.0, i.e. total annual profit will amount $ 214100.

Period of investment return will make 12.5 years after start of normal operation

II option - At tariff on 1 Gcal equal to $ 20.0 net profit from selling of 1 Gcal (after payment of all taxes and payments for licenses) will amount approximately $ 7.0, i.e. total annual profit will amount $ 374600

Period of investment return will make 7.2 years after start of normal operation

Note: Tariff for 1 Gcal of thermal energy generated in boiler with burning of gas can not be lower than $ 24.0

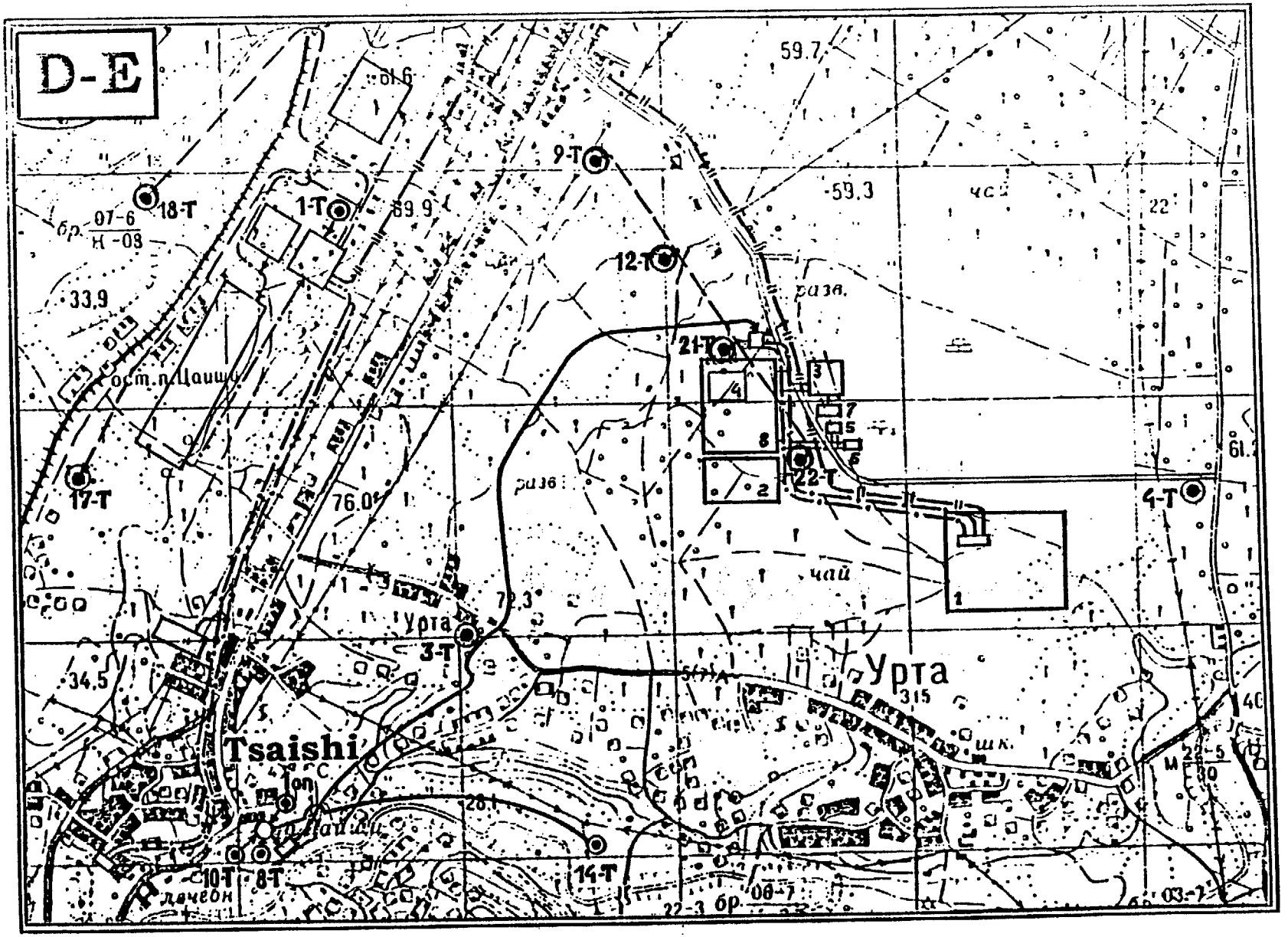
Design Proposal on Construction of Tsaishi Geothermal Heat Supply System (Tsaishi Area)

Principal Scheme

Design proposal given below describes possibility of utilization of geothermal potential of wells No. 1-OP, 8-T, 10-T and 14-T for construction of the Geothermal Heating Station, which will have enough capacity to supply heat to consumers from Tsaishi Agricultural Complex.

Design proposal envisages:

- obtaining geothermal water from productive wells No. 1-OP, 8-T, 10-T and 14-T in self-flow regime.
- preliminary treatment of geothermal water obtained from productive wells with use of vacuum degasator.
- transportation of degased geothermal water with use of pumps on the distance of 5.2 km by thermo-insulated pipeline up to the Geothermal Heating Station, located at reinjection wells(in construction of pipeline it's possible to use preserved sections of existing geothermal pipeline with total length of 4.0 km).
- thermal energy exchange between geothermal water and fresh water in secondary loop with use of plate-type heat-exchangers installed in the Geothermal Heating Station
- collection of cooled (used) geothermal water into tank with its further pumping (reinjection) into wells No. 9-T, 12-T, 21-T and 22-T.
- provision of circulation of heat carrier (fresh water) in secondary loop of heat supply system to consumers from Tsaishi Agricultural Complex.


D-E
18-T
1-T
9-T
12-T
21-T
22-T
4-T
17-T
3-T
14-T
10-T
8-T
Tsaishi
Урта
59.7
59.3
69.9
33.9
76.0
72.3
34.5
61.
40
22
ост. п. Цаиши
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07-6
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08-7
03-7
22-3
22-5
М 1:30

Consumers

Currently consumers of the Tsaishi geothermal heat supply system does not exist, if not to take into account the poultry farm, construction of which has not been completed.

In relation with this the proposal was aimed to select potential consumers of heat in order to achieve most effective utilization of potential of the Tsaishi Geothermal heat supply system.

Resolution of this problem led to selection of a set of enterprises, which conventionally are called the Tsaishi Agricultural Complex.

The following consumers of heat are recommended to be included in the Tsaishi Agricultural Complex:

1. Poultry farm with productivity 600 tonnes of chicken meat per year.
2. Greenhouse with heating of air and soil and productivity 1800 tonnes of vegetables per year.
3. Fishery with productivity 320 tonnes of fish per year.
4. Open fish pond with heating of water and productivity equal to 120 tonnes of fish per year.
5. Vegetable store - cooler with capacity 2000 tonnes of food products.
6. Tea leaves' and fruit dryer with productivity 1500 tonnes per yaer.
7. Mushroom farm with productivity 1500 tonnes per year.
8. Vegetable farm with soil heating and productivity 1500 tonnes of vegetables per year.

Creation of the Tsaishi Agricultural Complex with enterprises listed above will allow to reach most full utilization of heat of geothermal water and soften significantly the seasonal irregularities in heat consumption.

All recommended enterprises are large consumers of heat energy, i.e. share of expences on purchase of heat in total production cost of their products amounts 20-30%. Due to this it's profitable to place these enterprises near the source of cheap thermal energy, such as the Tsaishi geothermal heat supply system. As an additional argument for justification of reasonability of creation of the Tsaishi Agricultural Complex one can note that proposed compact location of various enterprises will allow some agricultural enterprises to process or utilize profitably products of other neighboring enterprises. For example:

- chicken droppings can be used as organic fertilizer in vegetable farm or as fish food in fishery.
- waste products of vegetable farm can be used as food for fish and chicken.
- reject products of fishery can be used as food for chicken.
- bed of fish pond which accumulates large amount of organic waste can periodically used as fertilazer in vegetable farm.

Therefore, one can conclude that investments in enterprises of the Tsaishi Agricultural Complex will be of high economic efficiency which will be based on the following factors:

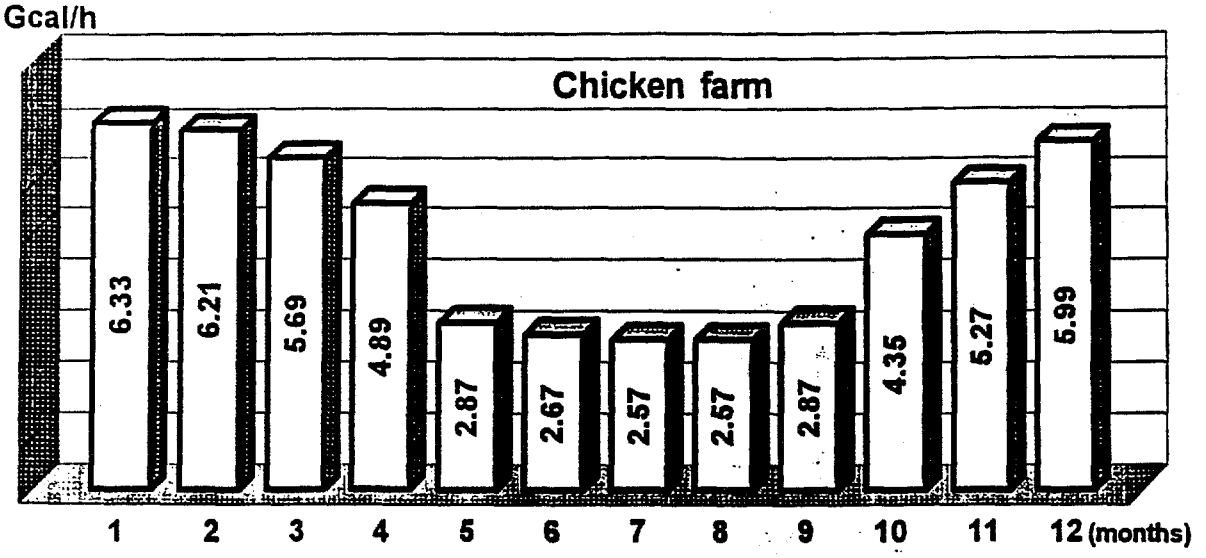
- favourable climatic and soil conditions,
- well developed transport communication network, which allows transportation of products by automobile road , railway and sea
- excess of labor resources,
- possibility of utilization of cheap geothermal energy,
- well developed river net, which is the cheap fresh water resource.

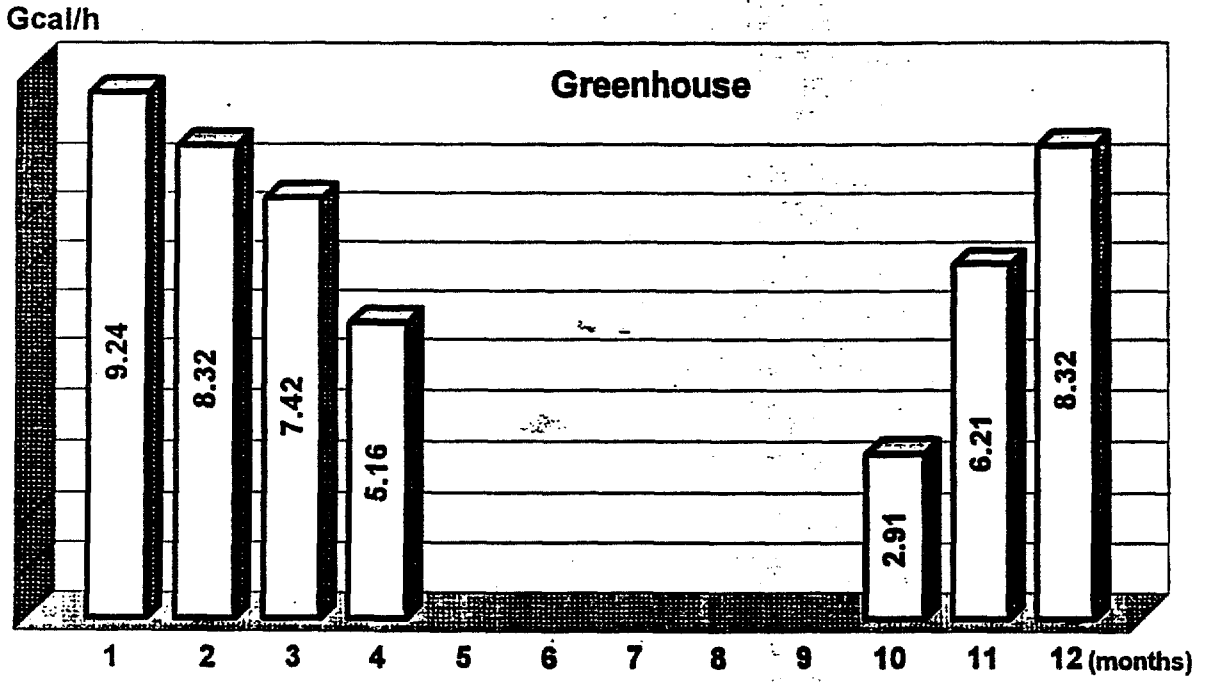
Combination of all above-mentioned factors can ensure low cost of production in enterprises of the Tsaishi Agricultural Complex.

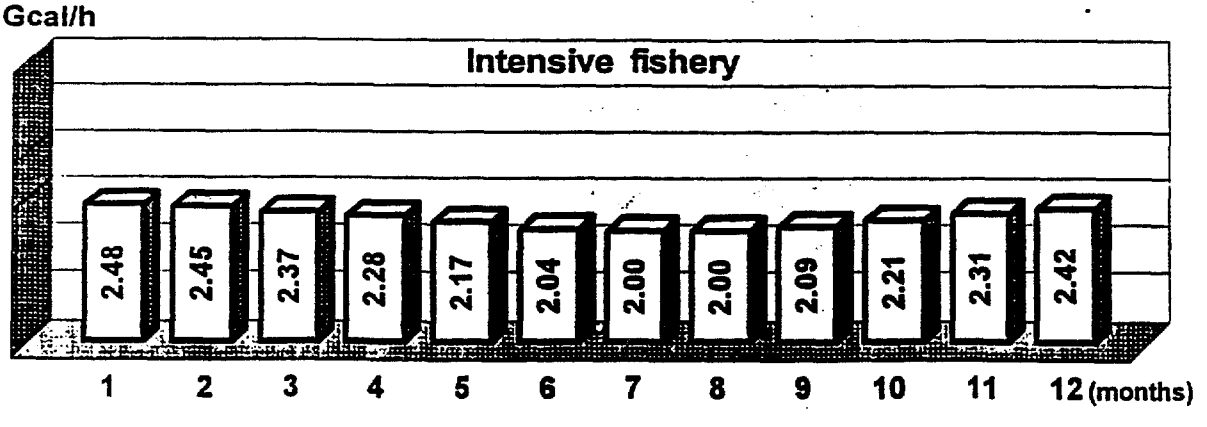
Estimated amount of investments needed for creation of enterprises of the Tsaishi Agricultural Complex lays in the following range:

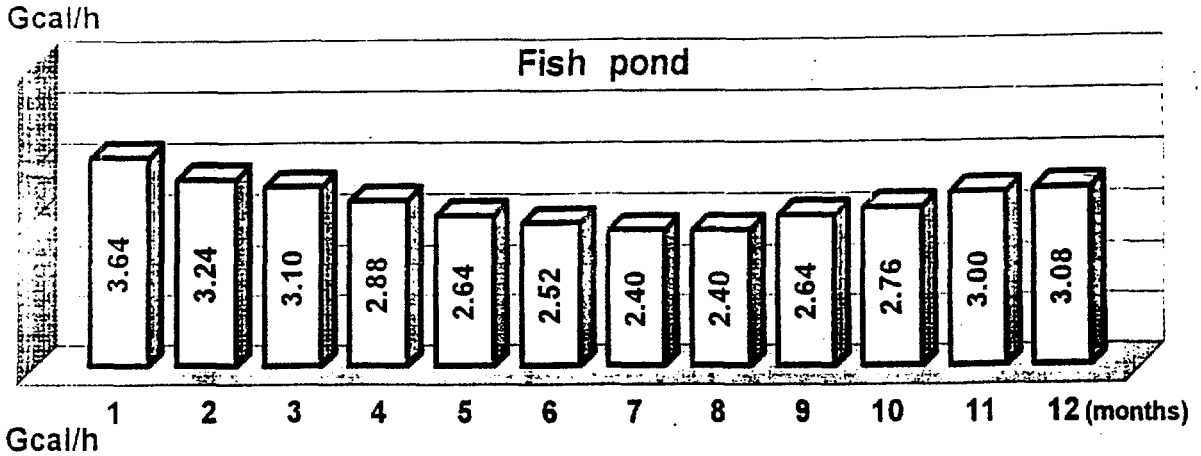
No.	Purpose of investments	Estimated amount of investments, million $
1	Completion of construction of the poultry farm and starting its operation, productivity 600 tonnes of chicken meat per year	2.3 - 2.6
2	Construction of greenhouse with heating of soil and provision of its operation, productivity 1800 tonnes per year	2.8 - 3.5
3	Construction of fishery and provision of its operation, productivity 320 tonnes of fish per year	2.0 - 2.4
4	Construction of open fish pons with system for water heating and provision of its operation, productivity 120 tonnes of fish per year	0.7 - 0.8
5	Construction of vegetable store (cooler) and provision of its operation, capacity 200 tonnes of food products	0.9 - 1.0
6	Construction of tea-leaf and fruit dryer and provision of its operation, productivity 1500 tonnes per year	0.9 - 1.0
7	Construction of mushroom farm with system for heating/cooling and provision of its operation, productivity 1500 tonnes of mushroom per year	3.9 - 4.2
8	Construction of vegetable farm with system for heating of open ground and provision of its operation, productivity 1500 tonnes of vegetables per year	1.0 - 1.1
	Total	**14.5 - 16.6**

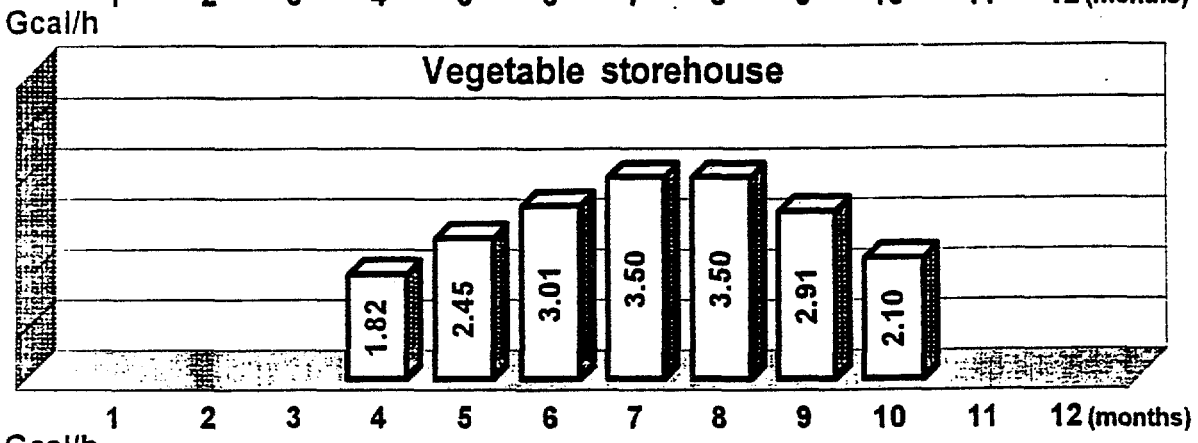
Chart of hourly consumption of thermal energy by various consumers of the Tsaishi geothermal system of heat supply versus months of the year.

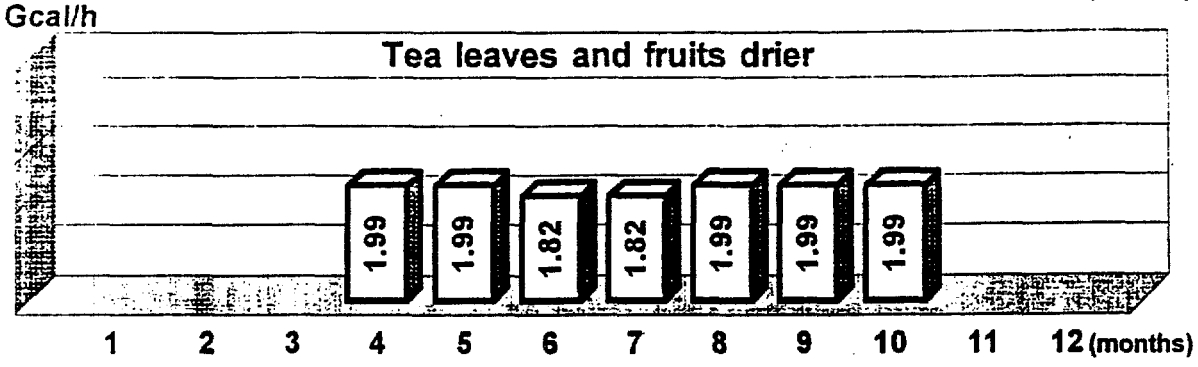


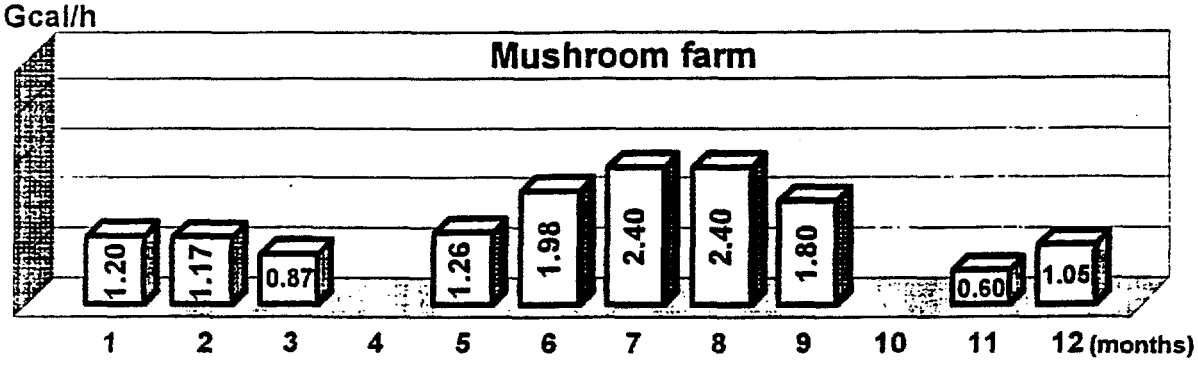


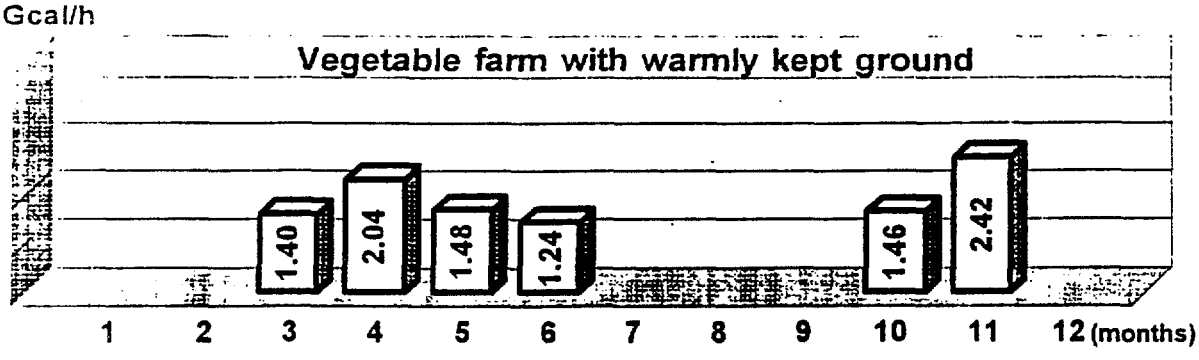



Gcal/h
Fish pond
3.64
3.24
3.10
2.88
2.64
2.52
2.40
2.40
2.64
2.76
3.00
3.08
1 2 3 4 5 6 7 8 9 10 11 12 (months)


Gcal/h
Vegetable storehouse
1.82
2.45
3.01
3.50
3.50
2.91
2.10
1 2 3 4 5 6 7 8 9 10 11 12 (months)


Gcal/h
Tea leaves and fruits drier
1.99
1.99
1.82
1.82
1.99
1.99
1.99
1 2 3 4 5 6 7 8 9 10 11 12 (months)


Gcal/h
Mushroom farm
1.20
1.17
0.87
1.26
1.98
2.40
2.40
1.80
0.60
1.05
1 2 3 4 5 6 7 8 9 10 11 12 (months)


Gcal/h
Vegetable farm with warmly kept ground
1.40
2.04
1.48
1.24
1.46
2.42
1 2 3 4 5 6 7 8 9 10 11 12 (months)

Summary chart of hourly consumption of thermal energy by all consumers of the Tsaishi geothermal system of heat supply versus months of the year.

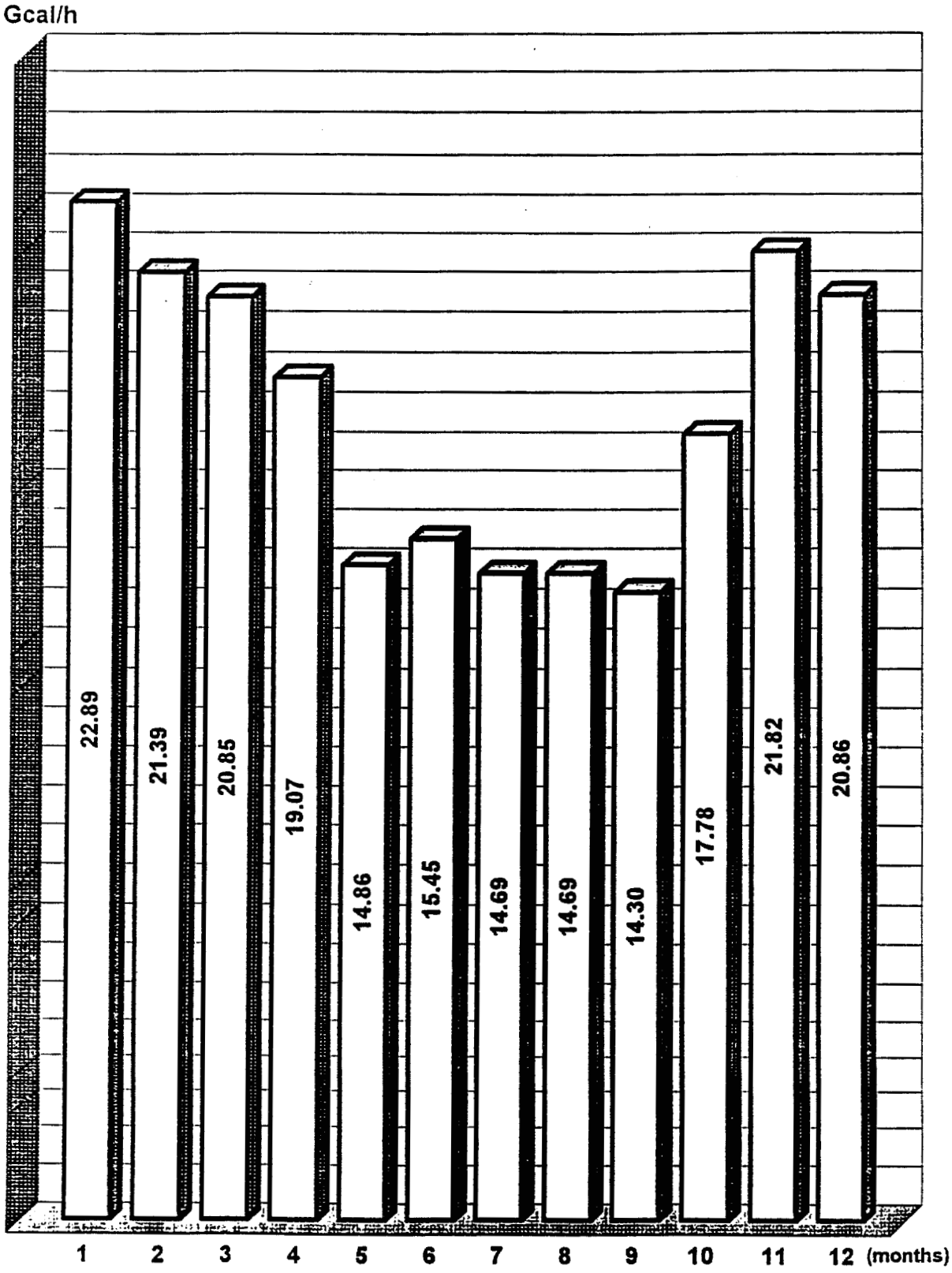


Table No.Ts-1

Heat energy consumption by users of Tsaishi geothermal heat supply system

Users		Purpose of thermal energy	Units	Months											
				I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average monthly ambient air temperature			^0C	4.9	5.5	8.2	12.3	17.0	20.3	22.6	22.7	19.2	15.1	10.5	6.7
1	Chicken farm	heating	Gcal/h	4.96	4.84	4.32	3.52	1.50	1.30	1.20	1.20	1.50	2.98	3.90	4.62
		hot water supply	"	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
2	Greenhouse	heating	"	7.18	6.48	5.78	4.06	-	-	-	-	-	2.91	4.83	6.48
		ground warmth-keeping	"	2.06	1.89	1.64	1.10	-	-	-	-	-	-	1.38	1.84
3	Intensive fishery	water heating	"	2.48	2.45	2.37	2.28	2.17	2.04	2.00	2.00	2.09	2.21	2.33	2.42
4	Fish pond	pond heating	"	3.64	3.24	3.10	2.88	2.64	2.52	2.40	2.40	2.64	2.76	3.00	3.08
5	Vegetable storehouse	cooling	"	-	-	-	1.82	2.45	3.01	3.50	3.50	2.91	2.10	-	-
6	Tea leaves and fruits drier	heating	"	-	-	-	-	1.99	1.99	1.82	1.82	1.99	1.99	1.99	-
7	Mushroom farm	heating	"	1.20	1.17	0.87	-	-	-	-	-	-	-	0.60	1.05
		cooling	"	-	-	-	-	1.26	1.98	2.40	2.40	1.80	-	-	-
8	Vegetable farm with warmly kept ground	ground heating	"	-	-	1.40	2.04	1.48	1.24	-	-	-	1.46	2.42	-
	Total consumption			22.89	21.39	20.85	19.07	14.86	15.45	14.69	14.69	14.30	17.78	21.82	20.86
	Duration of period		hour	744	678	744	720	744	720	720	744	720	744	720	744
	Total average monthly consumption		Gcal	17030	14500	15510	13730	11050	11120	10570	10930	10300	13220	15710	15520
	Total annual heat energy consumption		Gcal	- 159 190											

Table No.Ts-2

Use of heat carrier in secondary loop of Tsaishi geothermal heat supply systems

	Consumers	Purpose of heat carrier	Potential of heat carrier	Unit of measure	Months											
					I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	Average monthly air temperature			^0C	4.9	5.5	8.2	12.3	17.0	20.3	22.6	22.7	19.2	15.1	10.5	6.7
1	Poultry farm	Heating	75^0 C-55^0C	m^3/h	248	242	216	176	75	65	60	60	75	149	195	231
		Hot water supply	75^0 C-20^0C	m^3/h	25	25	25	25	25	25	25	25	25	25	25	25
2	Greenhouse	Heating	75^0 C-40^0C	m^3/h	205	185	165	116	-	-	-	-	-	83	138	185
		ground warmth-keeping	40^0 C-20^0C	m^3/h	103	92	82	55	-	-	-	-	-	-	69	92
3	Intensive fishery	water heating	75^0 C-55^0C	m^3/h	-	-	-	-	67	92	100	100	84	-	-	-
		water heating	55^0 C-40^0C	m^3/h	165	163	158	152	55	13	-	-	27	147	155	161
4	Fish pond	pool heating	40^0 C-20^0C	m^3/h	182	162	155	144	132	126	120	120	132	138	150	154
5	Vegetable storehouse	cooling	75^0 C-40^0C	m^3/h	-	-	-	52	70	86	100	100	83	60	-	-
6	Drier	heating	75^0 C-40^0C	m^3/h	-	-	-	-	57	57	52	52	57	57	57	-
7	Mushroom farm	heating	55^0 C-40^0C	m^3/h	80	78	58	-	-	-	-	-	-	-	40	70
		cooling	55^0 C-40^0C	m^3/h	-	-	-	-	84	132	160	160	120	-	-	-
8	Warmly kept ground	ground heating	40^0 C-20^0C	m^3/h	-	-	70	102	74	62	-	-	-	74	121	-

Table No.Ts-3

Parameters of heat carrier in secondary loop of Tsaishi geothermal heat supply systems

Parameter of heatcarrier	Heatcarrier potential	Units	Months											
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Supplied heatcarrier volume	75°C	m^3/h	478	452	406	369	294	325	337	337	324	374	415	441
	55°C	"	248	242	216	176	142	157	160	160	159	149	195	231
	40°C	"	450	426	381	320	266	288	312	312	287	347	390	416
Volume of heatcarrier to be used	75°C	"	478	452	406	369	294	325	337	337	324	374	415	441
	55°C	"	245	241	216	152	139	145	160	160	147	147	195	231
	40°C	"	285	254	307	301	206	188	120	120	132	211	340	246
Volume of heatcarrier not to be used	75°C	"	0	0	0	0	0	0	0	0	0	0	0	0
	55°C	"	3	1	0	24	3	12	0	0	12	12	0	0
	40°C	"	165	172	74	19	60	100	192	192	155	136	50	170
	20°C	"	310	279	332	326	231	231	145	145	157	236	365	271
Temperature of used heatcarrier mixture		°C	27.1	27.7	23.7	23.3	24.4	27.5	31.4	31.4	30.9	27.5	22.4	27.7

Table No.Ts-4

Parameters of heatcarrier circulating in primary (geothermal) loop
of Tsaishi geothermal heat supply systems

Parameter of heatcarrier	Units	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Geothermal water temperature at heatexchanger inlet	^0C	82	82	82	82	82	83	83	83	83	82	82	82
Geothermal water temperature at heatexchanger outlet	"	32.1	32.7	28.7	28.3	29.4	32.5	36.1	36.4	35.9	32.5	27.4	32.7
Volume of extracted and injected geothermal water	m^3/h	459	434	391	355	283	300	313	313	304	359	400	423

Table No.Ts-5

Electric power consumption in primary loop of Tsaishi geothermal heat supply systems
(for transportation and reinjection of geothermal water)

Design parameters	Units	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Volume of transported and pumped geothermal water	m^3/h	459	434	391	355	283	300	313	313	304	359	400	423
Number of working pumps TsNSG 180-85 providing geothermal water transportation	it.	3	2	2	2	2	2	2	2	2	2	2	2
Total capacity of working pumps TsNSG 180-85	MW	0.225	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Number of working pumps TsNSG 180-212 providing geothermal water reinjection	it.	3	2	2	2	2	2	2	2	2	2	2	2
Total capacity of working pumps TsNSG 180-212	MW	0.48	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Pumps working period	h	744	678	744	720	744	720	720	744	720	744	720	744
Average monthly amount of electric power consumed by pumps TsNSG 180-85	MW.h	167.4	101.7	111.6	108.0	111.6	108.0	108.0	111.6	108.0	111.6	108.0	111.6
Average monthly amount of electric power consumed by pumps TsNSG 180-212	MW.h	357.2	217.0	238.1	230.4	238.1	230.4	230.4	238.1	230.4	238.1	230.4	238.1
Other electric power consumption	MW.h	45.0	40.5	45.0	42.0	45.0	42.0	42.0	45.0	42.0	45.0	42.0	45.0
Total amount of consumed electric power per year	MW.h												

Total annual electric power consumption - 4804.3 MWh

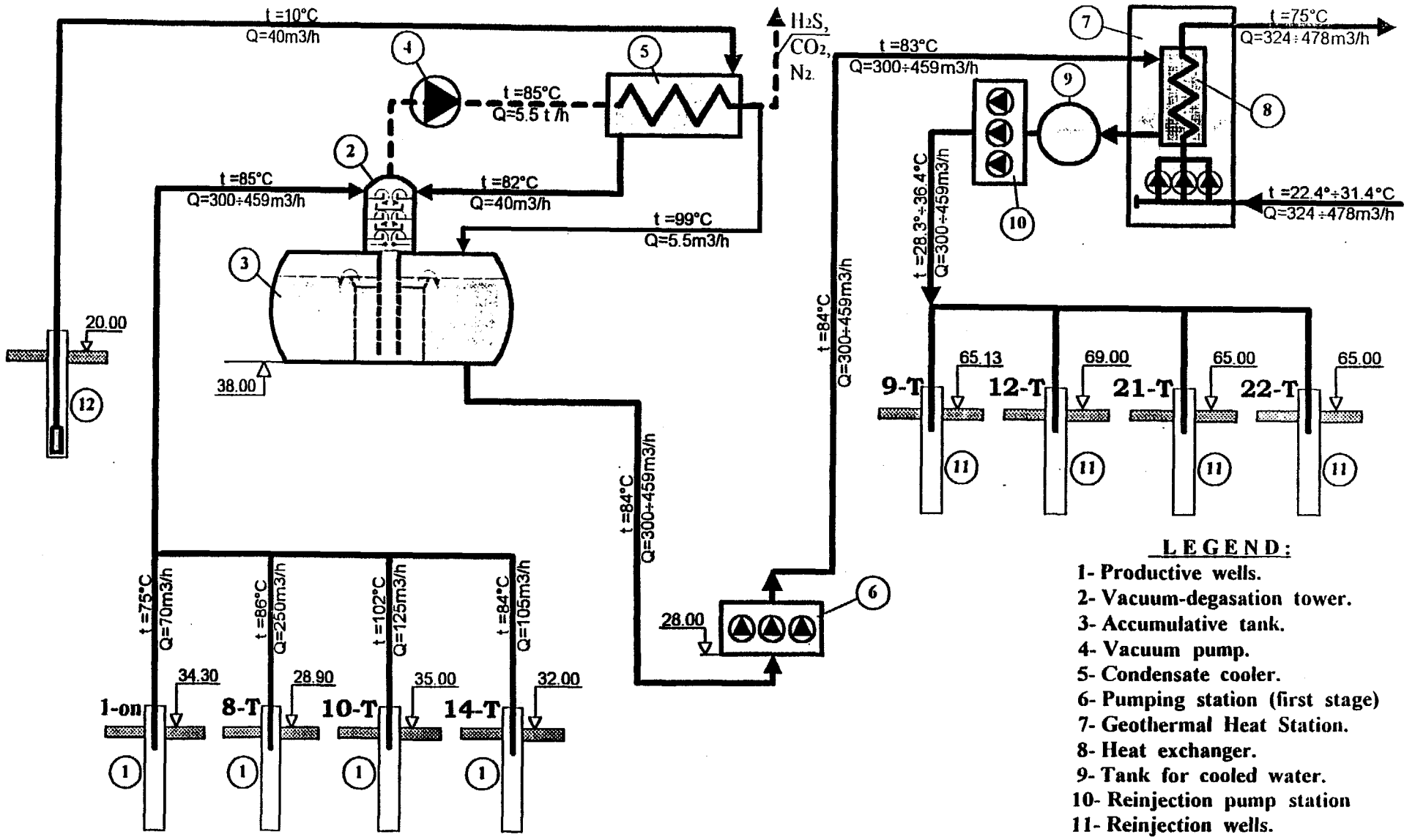
Table No.Ts-6

Electric power consumption in secondary loop of Tsaishi geothermal heat supply systems
(for heatcarrier circulation)

Design parameters	Units	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Volume of circulating heatcarrier	m^3/h	478	452	406	369	294	325	337	337	324	374	415	441
Number of working pumps K90/65	item	5	4	4	4	3	3	3	3	3	4	4	4
Total capacity of working pumps	MW	0.15	0.12	0.12	0.12	0.09	0.09	0.09	0.09	0.09	0.12	0.12	0.12
Pumps working period	h	744	678	744	720	744	720	720	744	720	744	720	744
Average monthly amount of electric power consumed by pumps	MW.h	111.6	81.4	89.3	86.4	67.0	64.8	64.8	67.0	64.8	89.3	86.4	89.3
Other electric power consumption	MW.h	15.0	13.5	15.0	14.0	15.0	14.0	14.0	15.0	14.0	15.0	14.0	15.0

Total annual electric power consumption - 1135.6 MWh

Tsaishi Geothermal System of Heat Supply.
Principal Scheme of Primary (Geothermal) Loop.

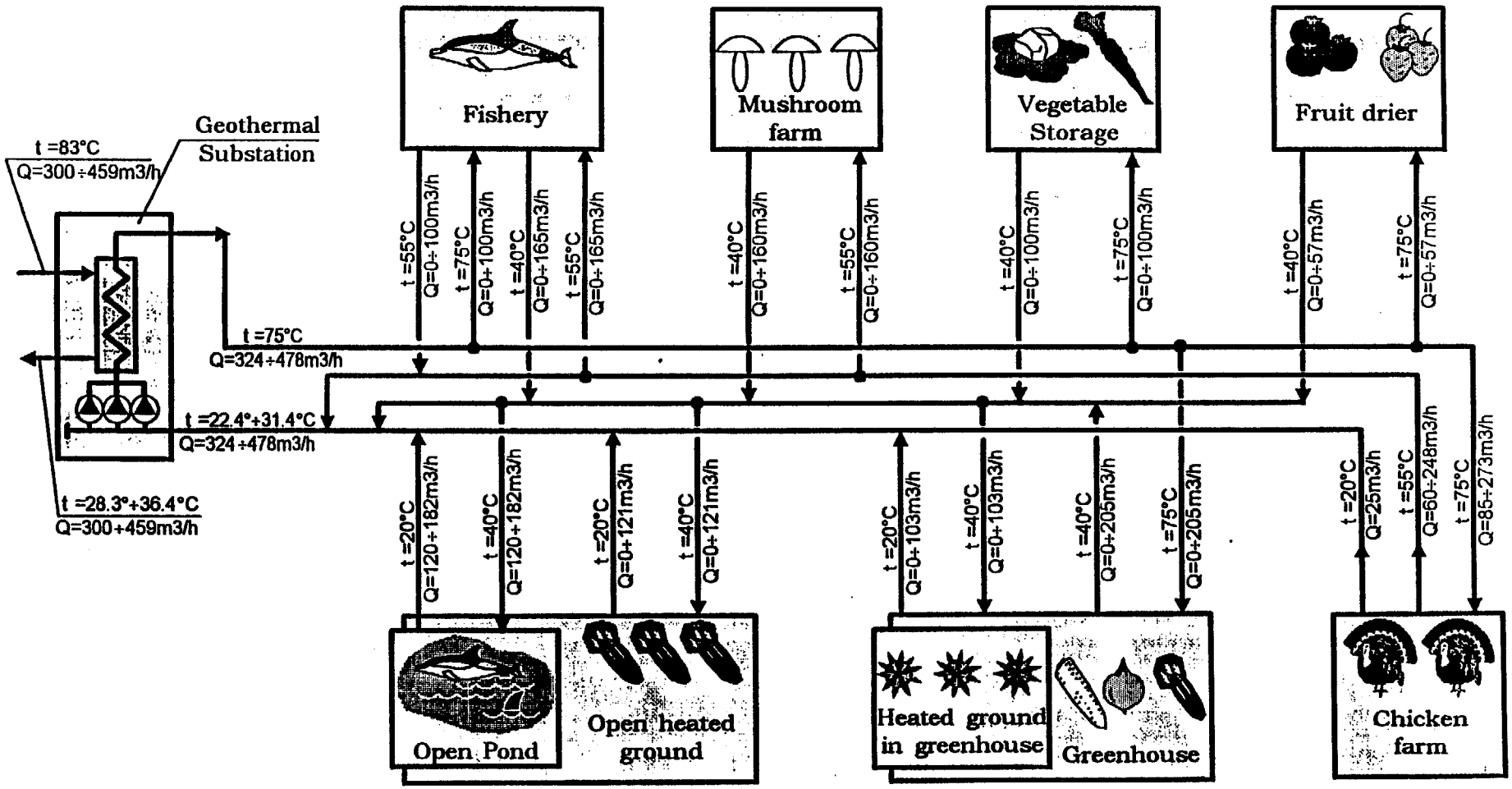


LEGEND:

1- Productive wells.
2- Vacuum-degasation tower.
3- Accumulative tank.
4- Vacuum pump.
5- Condensate cooler.
6- Pumping station (first stage)
7- Geothermal Heat Station.
8- Heat exchanger.
9- Tank for cooled water.
10- Reinjection pump station
11- Reinjection wells.
12- Cold water well.

Tsaishi Geothermal Heat-Supply System.

Scheme of Heat Supply to Consumers at Tsaishi Agricultural Complex (secondary loop)



Tentative Budget for Development of Tsaishi Heat Supply Geothermal System

A. Development of primary (geothermal) loop of heat supply system

Chapter 1. Rehabilitation and modification of geothermal water extraction and treatment system

N.N	Item	Unit	Quantity	Price thousand $	
				per item	total
1.1	Rehab. of head-part of existing productive wells OP-1, 8-T, 10-T, 14-T	item	4	5.0	20.0
1.2	Installation of collector tank of 50 m^3	item	2	20.0	40.0
1.3	Installation of degassing tower of DCB-300 type	item	2	10.0	20.0
1.4	Installation of vacuum-pump of HB-3-100D type	item	3	8,5	25.5
1.5	Installation of steam condenser of OBA-24 type	item	2	5.5	11.0
1.6	Installation of thermoinsulated pipelines from productive wells to the collector tank	m	600	0,08	48.0
1.7	Well drilling (depth 50 m) for extraction of cold filtrates of r.Jumi	item	2	12.5	25.0
1.8	Outfitting of cold water wells with deep-water pumps of ATH10-6 type	item	2	8.5	17.0
1.9	Installation of low voltage line of power supply and power equipment				8.0
1.10	Rehab. of access roads and arrangement of territory around productive wells				20.0
	Total for Chapter 1				234.5

Chapter 2. Rehabilitation and modification of geothermal water transportation system.

N.N	Item	Unit	Quantity	Price thousand $ per item	total
1	2	3	4	5	6
2.1	Rehab. of existing building of Pump Station	m^2	120	0,15	18.0
2.2	Installation of pump of type TsNSG 180/85	item	4	9.5	38.0
2.3	Rehab. of existing power supply high-voltage line and installation of electric equipment of the pump station	item			18.0
2.4.	Installation of thermoinsulated pipeline from accumulative tank to the pump station	m	100	0.08	8.0
2.5.	Rehab. and thermal insulation of existing pipeline from pump station to geothermal thermal station	m	4000	0.025	100.0
2.6.	Installation of missing section of pipeline to the geothermal thermal station	m	1200	0.08	96.0
	Total for Chapter 2				278.0

Chapter 3. Development of geothermal power station and system for cooled (treated) geothermal water reinjection.

N.N	Item	Unit	Quantity	Price thousand $ per item	total
3.1	Construction of thermal station building	m^2	300	0.3	90.0
3.2	Installation of plate corrosion-resistant heat exchangers	set	14	15.0	210.0
3.3	Installation of reinjection pumps of type TsNSG180/212	item	4	17.5	70.0
3.4	Installation of pump of type K 100-65-200, providing circulation of heat carrier in secondary loop of heat supply system	item	6	2.9	17.4
3.5	Installation of pump of type KC-20-50, providing adding up of heat carrier in secondary loop of heat supply system				
3.6	Installation of equipment of water treatment and sodium-cationic filters				
3.7	Construction of ferro-concrete reservoir with volume 100 m^3 for cooled geothermal water	item	1	12.0	12.0
3.8	Construction of ferro-concrete reservoir with volume 100 m^3 for fresh water	item	1	12.0	12.0
3.9	Installation of pipelines on the territory of thermal station	m	300	0.06	18.0
3.10	Installation of electrical equipment of thermal station				15.0
3.11	Rehab. of head-part of existing reinjection wells: 9-T, 12-T, 21-T, 22-T	item	4	5.0	20.0
3.12	Installation of pipelines from thermal station to reinjection wells	m	1500	0,035	52.5
3.13	Installation of low voltage power supply line	m	1500	0,012	18.0
3.14	Arrangement of access road and territory of thermal station and reinjection wells				35.0
3.15	Installation of I&C and technological process automatization system				150.0
	Total for Chapter 3				752.4

Installation of secondary (fresh) loop of heat supply system

Chapter 4. Installation of distributing thermal network for service of Tsaishi Agricultural Complex consumers

N	Item	Unit	Quantity	Cost, thousand $	
				per item	Total
1	2	3	4	5	6
4.1.	Installation of thermoinsulated pipeline Ø 400 mm	m	600	0.1	60.0
4.2.	Installation of thermoinsulated pipeline Ø 300 mm	m	200	0.075	15.0
4.3.	Installation of thermoinsulated pipeline Ø 250 mm	m	2000	0.06	120.0
4.4	Installation of thermoinsulated pipeline Ø 200 mm	m	800	0.037	29.6
4.5	Installation of thermoinsulated pipeline Ø 150 mm	m	3000	0.023	69.0
	Total for chapter 4				293.6

Chapter 5. Participation of Enterprise "Tsaishi Heat Supply Geothermal System" in construction of internal engineering communications at Tsaishi Agricultural Complex

N	Item	Unit	Quantity	Cost, thousand $	
				per item	Total
1	2	3	4	5	6
5.1.	Share of participation in rehabilitation of existing water pipeline	%	20	4.0	80.0
5.2.	Share of participation in rehabilitation of existing high voltage power supply line and transformer substation	%	20	1.5	30.0
5.3.	Share of participation in construction of sewage and drainage facilities	%	5	10.0	50.0
5.4	Share of participation in construction of roads	%	5	5.0	25.0
5.5	Share of participation in arrangement of communications	%	10	2.0	20.
	Total for Chapter 5				205.0

C. Other expenses

Chapter 6. Explorations and design works, registration of rights for used land lots

N	Item	Unit	Quantity	Cost, thousand $	
				per item	Total
1	2	3	4	5	6
6.1.	Performance of test pumping in reinjection wells 9-T and 12-T				54.1
6.2.	Working out of detailed design of Tsaishi heat supply geothermal system	% of total for Chapter1÷ Chapter5	8	17.6	140.8
6.3.	Technical supervision and acceptance of performed work in the process of construction	"	3	17.6	52.8
6.4	Registration of rights for land lots, previously used in agriculture		2.5	300	750.0
	Total for Chapter 5				977.7

TOTAL FOR CHAPTERS 1 ÷ 6

Note: Position 6.4 can be corrected depending on changes in legislation on land use rules in Georgia.

Annual expences needed for operation of the Tsaishi geothermal heat supply system

	Type of Expences	Total Annual, Thousand $
	I. Operational expences	
1.1	Expences on purchase of electric energy in amount of 5940 MW.hour at cost of 1 MW.hour - $ 36.0	213.84
1.2	Expences on purchase of other materials and services	60.0
1.3	Expences on current repairs of equipment, buildings and constructions in amount of 5% of summ of capital expences on construction of geothermal system (chapter 1 - chapter 5)	88.5
1.4	Expences on labor cost for personnel (15 persons), including payments for social insurance and medical insurance of personnel	63.0
	II. Depreciation charges	
2.1	Depreciation charges on condition of 25 year term of operation of geothermal system	70.8
	Total	496.14

Cost of thermal energy

At selling of thermal energy in amount of 159190 Gcal per year and with annual operational expences in amount of $ 496140 US dollars

Cost of 1 Gcal = $ 3.12

Economic effectivity of investments

At tariff on 1 Gcal equal to $ 12.5 net profit from selling of 1 Gcal (after payment of all taxes and payments for licenses) will amount approximately $ 5.5, i.e. total annual profit will amount $ 875500.

Period of investment return will make 3.2 years after start of normal operation

Note: Tariff for 1 Gcal of thermal energy generated in boiler with burning of gas can not be lower than $ 24.0

Comment: presented proposal was not aimed to consider possibility of creation of the Western-Tsaishi geothermal system of heat supply (Western Tsaishi area), because its assumed that problems related with this system are similar to ones considered in design proposal on Tsaishi geothermal system of heat supply.