The report is approved:

From ISTC	From Contracting Institute	From the Partner
Norbert Jousten Executive Director (date)	Gumarbek Zh. Daukeev Rector (date)	William E. Freeman NIS Program Director (date)

ANNUAL REPORT

for the second year

on ISTC K-1240p project

“Post-containment Management and Monitoring of Mercury Pollution in Site of Former PO “Khimprom” and Assessment of Environmental Risk Posed by Contamination of Groundwater and Adjacent Water Bodies of the Northern Industrial Area of Pavlodar”

Contracting Institute:
Non-profit JSC “Almaty Institute of Power Engineering and Telecommunications”, BG Chair of Environmental Technology

Participating Institutes:
1. Institute of Hydrogeology and Hydrophisics (IHH)
2. JSC “Kaustik” (Kaustik)
3. Pavlodar State University (PSU)
4. JSC “Biomedpreparat – Engineering Center” Laboratory of Monitoring (BMP)

Manager of the project:
Mikhail Alexeevich ILYUSHCHENKO,
Office tel.: 8 3272 923454 (ext.106), fax: 8 3272 924461, e-mail: mai@aipet.kz

Commencement Date: 1 October 2005, Duration: 36 months

Almaty 2007

6. Brief description of the work plan: objective, expected results, technical approach:

6.1. Objectives of the project

I. to identify the risk associated with the spread of groundwater plumes contaminated with mercury, including their movement through the network of water intake boreholes in village Pavlodarskoye, and further towards river Irtysh and/or their rise onto the pastures and, if significant, identify a management strategy to contain risk;

II. to identify a management strategy for containing the environmental risk, caused by the mercury pollution of lake Balkyldak, including the pathway of pollutants bioaccumulation via food chains;

6.2. Expected results

The reported study is an applied research in the field of environmental protection. It is assumed that in the course of this works new facts might be revealed that would require the deepening and the extension of the research.

- One of the most important results of proposed study will be the foundation of monitoring laboratory of Kaustik that will be capable to implement Post-containment monitoring Program in Northern industrial area of Pavlodar during 2005-2020 and to conduct other investigations in the field of environmental protection. The completion of Phase I of Demercurization Project does not assume termination of the investigation of mercury pollution in Pavlodar. The Phases II and III are starting that will require more detailed and more extensive studies of the residual mercury pollution and associated risk. These reasons will allow the laboratory of Kaustik to become self-supporting;
- Kaustik together with AIPET will carry out the monitoring study of the mercury contamination of groundwater in the Northern industrial area of Pavlodar;
- AIPET together with Kaustik will study the extent of mercury contamination of pastures in the areas where the upward movement of polluted groundwater is possible;
- BMP together with Kaustik will conduct the monitoring study regarding to mercury contaminated soilss in Northern industrial area of Pavlodar;
- AIPET together with PSU will determine the levels of total mercury content in bottom sediments and biota from wastewater storage pond – lake Balkyldak;
- AIPET together with IHH will assess the risks associated with the residual mercury contamination of groundwater and wastewater storage pond – lake Balkyldak;
- IHH will upgrade the groundwater model for the Northern industrial area of Pavlodar and make it more accurate. IHH will make forecasts for the future spread of groundwater contaminated with Hg;
- AIPET together with IHH will draw up and discuss with local stakeholders and state authorities the proposals for risk management in Northern outskirts of Pavlodar including possible implementation of additional work on PO “Khimprom” demercurizing and/or brining wastewater storage pond – lake Balkyldak to safe conditions.

6.3. Technical Approach

During sampling and chemical analyses the methods recommended by US EPA will be used as well as standard procedures on Quality Control/Quality Assurance accepted in the West. Determination of mercury in solid samples will be carried out using AAS analyzer (Lumex RA

915+); AFS analyzer (PS Analytical Millennium Merlin System) will be used for Hg determination in water samples and biological tissues.

Assessment and management of risk associated with groundwater contamination will be carried out using hydrogeological models received by means of the ModFlow GMS 5.0 software. The preliminary assessment of risk (Tier 1 of risk assessment) posed by mercury contamination of pastures and fish will be conducted using the monitoring of the level of mercury pollution and subsequent comparison of pollution indices with existing state standards and guidelines values.

8. Technical progress during the second year

8.1. Work performed in compliance with tasks and milestones

8.1.1 Study of the movement of mercury in the groundwater rise in depressed area in saturated and unsaturated zones and its accumulation in the shallow ponds, soil and vegetation. Development of management strategy to contain the risk to population in the vicinity and livestock (Task 1)

8.1.1.1 *Groundwater survey*: in September-October of 2007 groundwater samples were taken from 81 hydro-geological observation boreholes for total mercury determination, at the same time groundwater tables were measured in 154 observation boreholes.

8.1.1.2. *2 integral samples of gramma grass were taken* within the area which was used as a pasture for livestock by population of Pavlodarskoe village.

8.1.1.3. *111* s*oil samples have been analyzed* taken in 2006 from topsoil (0-10 cm) from 5 places of mercury contaminated groundwater possible rise at the territory between the industrial site #1of Pavlodar Chemical Plant (PCP) and wastewater storage pond – Lake Balkyldak.

8.1.1.4. Computer “Summary tables of 01 - 03.2007” which formed the *database of post-demercurization monitoring in the industrial area of former PO “Khimprom”, Pavlodar have been compiled* on the results of field study and chemical analytical works.

8. 1.1.5. *The map of soil mercury contamination produced in 2002* (fig.1, Annex 1) *has been made more accurate based on the results of determination of mercury concentrations in soil*.

8. 1.1.6. The results of determination (2007) of *mercury concentration in groundwater* at the area of mercury pollution (“Summary table 02.2007) *have been inserted on the vector map* together with the results of similar research of 2004, 2005 and 2006 (fig.2, Annex 1).

8.1.2. Assessment of possibility for mercury-polluted groundwater flow to change its direction; study of interaction of contaminated groundwater with bearing strata and underlying aquifers (Task 2):

8.1.2.1. *Calibration of the local model of hydro-geological conditions* at the area of groundwater mercury contamination has been completed.

8.1.2.2. To assess the risk of the soil mercury contamination as a result of the contaminated groundwater rise to the ground surface followed by their evaporation *analysis of characteristics of hydro-geological conditions at the investigated area as well as the results of the modeling was carried out* with a view to reveal spots with high possibility for mercury there to get to zone of aeration.

8.1.2.3. *The laboratory experiment to study sorption equilibriums* in the system: bearing strata (loamy sand taken in the Northern industrial area of Pavlodar) – $HgCl_2$ solution *was conducted* and *sorption coefficients were determined* for computer simulation of hydro-geological processes.

8.1.3. Creation of a map of soils mercury contamination in Northern industrial area of Pavlodar with a view to develop a feasibility study of their clean up (Task 3):

8.1.3.1. *Soil Sampling Plan were produced and delivered to Participant Institution JSC "Kaustik"* to create a map of soil mercury contamination for 2007-2008: the table with sampling points coordinates and 3 maps with sampling points location (fig. 3-5, Annex 1). The staff of Kaustik was trained in work with portable GPS to find the sampling points as well as in soil sampling procedures, the sample storage and samples preparation for chemical analysis.

8.1.4. Assessment of possibility to contain the risk posed by mercury pollution of Lake Balkyldak including the fish within it (Task 4)

8.1.4.1. *Bottom sediments sampling and measurement of soft sediment thickness in wastewater storage pond – Lake Balkyldak:* in March, 2007 159 bottom sediment samples were taken from under the ice in 94 sampling points and in September, 2007 35 samples – along the coastline within reed-bed areas in 35 sampling points.

8.1.4.2. *The final version of the computer map of depths of wastewater storage pond Balkyldak and thicknesses of its bottom sediment has been produced* within GIS of Lake Balkyldak using software ArcGIS, module Spatial Analyst.

8.1.4.3. *Biota sampling for chemical analysis for total mercury content:* in May-September, 2007 fish – 60 samples, benthos and plankton organisms – 8 and 9 integral samples respectively - *from wastewater storage pond – Lake Balkyldak;* benthos organisms – 3 integral samples - *from water catchment of the pond Balkyldak*; fish – 30 samples, benthos organisms – 3 integral samples *– from the control water body – Lake Krivoe.* At the same time *mass measurements of fish were carried out for their morphological analysis: 3 – on wastewater storage pond – Lake Balkyldak and 1- on Lake Krivoe.*

8.1.4.4. *Morphological analysis of fish samples were carried out* which were caught in both 2006 and 2007.

8.1.4.5. Computer summary tables (Summary tables 04 - 07.2007), which formed the *database of wastewater storage pond – Lake Balkyldak mercury monitoring* were compiled based on the results of field study at Lake Balkyldak.

8.1.4.6. The results of determination of mercury concentration in bottom sediment samples ("Summary table 08.2006") were used to *create preliminary vector map "Mercury contamination of bottom sediments of wastewater storage pond Balkyldak"* and *preliminary calculation of amount of mercury* deposited in the bottom sediments of the pond.

8.1.4.4. *Morphological analysis of fish samples were carried out* which were caught in both 2006 and 2007.

8.1.4.5. Computer summary tables (Summary tables 04 - 07.2007), which formed the *database of wastewater storage pond – Lake Balkyldak mercury monitoring* were compiled based on the results of field study at Lake Balkyldak.

8.1.5. To draw up and discuss with local stakeholders the recommendations for the 2nd stage of demercurization and other remediation activities in the area of the former PO "Khimprom" (Northern industrial area of Pavlodar), including the recommendation for abolishment or further safe use of the wastewater storage pond – Lake Balkyldak (Task 5)

8.1.5.1. On December 22, 2006 *Public Talks on the results of investigation of the wastewater storage pond – Lake Balkyldak was conducted* in Pavlodar within the framework of ISTC K-1240p project (deputies of oblast maslikhat, officials from ecological and sanitary and epidemiological departments, PCP administration attended the talks). The event was highlighted by two oblast TV channels (Kazakhstan-Pavlodar and Irbis). The data of 2006 on total mercury content in bottom sediments and fish from the wastewater storage pond Balkyldak were discussed which showed substantial potential risk posed by this technical water body. Also both *"Science based recommendations on arrangement of wastewater storage pond Balkyldak monitoring" and "Research Program of the wastewater storage pond Balkyldak"* which were developed in September, 2006 (see ISTC K-1240p project Annual report for the first year, section 8.1.5.2.) *were discussed, approved* and adopted as official documents for Pavlodar Oblast Akimat. *Possibilities of radical change in the pond ichthyocenosis structure were discussed* as well.

8.1.5.2. *The results of investigation of soil mercury contamination within the industrial site #1 of PCP and in the vicinity* (section 8.2.3.3. of this report and fig.1, Annex 1), *mercury emission to atmosphere* (ISTC K-1240p project Annual report for the first year, section 8.2.2.3.4.) *and infiltration of soluble mercury forms from contaminated soils down to groundwater* (section 8.2.3.2. of this report and fig.2, Annex 1) were discussed with administrations of both Pavlodar Territorial Department of Environmental Protection and PCP. This induced Pavlodar Territorial Department of Environmental Protection to address a request to managers of ISTC K-1240p project to expand the program of investigation of the soil mercury contamination with a view to prepare a feasibility study of the soil remediation. In this connection the *Task 3 of the Work Plan of the project was discussed and changed and the Soil Sampling Plan* (section 8.1.3. of this report and fig. 3-5, Annex 1) *was prepared* which was delivered to JSC "Kaustik" *for conducting field and chemical -analytical works both within the frameworks of ISTC K-1240p project and at the cost of some other funding sources*.

8.1.5.3. The progress of demercurization and monitoring works in Pavlodar was reported at *BIOMERCURY Workshop in Southampton, UK (19-23 February, 2007).*

8.1.5.4. *International Scientific Workshop "Environmental Mercury Pollution: Mercury Emissions, Remediation and Health Effects"* was held on 28 May – 1 June, 2007 in Astana, Kazakhstan with the support of Global Partnership Program of Canadian Government, Ministry of Environment Protection of the Republic of Kazakhstan and ISTC. One of the purposes of the workshop was evaluation of technical solutions and exchange of experience in remediation of mercury polluted areas (cases of demercurization projects conducted in Pavlodar and Temirtau, Kazakhstan). 42 specialists from Kazakhstan, Russia, Canada, USA, UK participated in the workshop. 25 presentations were done including 8 ones related to mercury pollution in Pavlodar. 4 presentations contained the results obtained on ISTC K-1240p project. Within the frameworks of the workshop the special technical tour was arranged and held successfully for the participants to visit the site of mrcury pollution in the Northern industrial area of Pavlodar and to meet with specialists from Pavlodar Territorial Department of Environmental Protection. Also specialists from Ministry of Environment Protection of the Republic of Kazakhstan, Ministry of Industry and Trade of the Republic of Kazakhstan, Committee for Water Resources of the Ministry of

Agriculture of the Republic of Kazakhstan took part in the workshop activity which was covered by the republican TV.

8.1.5.5. On August 21, 2007 PSU, public fund "Partnership Center" and Tourism division of Pavlodar oblast Department of Physical Training and Sports *held bicycle race around the wastewater storage pond Balkyldak in Pavlodar* within the framework of "Eco-tourist 2007" Program. Pupils of the secondary school no. 40 located in Pavlodarskoe village as well as PSU students participated in the bicycle race. During the cycle race where 10 cyclists - pupils of the secondary school no. 40 of Pavlodarskoe village were accompanied by a car of motorway police and a bus with medical staff and support group (the escort of 15 people) halts were made near some places of regular environment observations. During such halts PSU students talked to the bicycle race participants about history of the natural Lake Balkyldak and its transformation into a wastewater storage pond, its present technical status, influence on the environment and showed techniques of environmental research, methods of sampling and so on. The results of the bicycle race were summed up at the workshop "Eco-tourist 2007" held in the secondary school no.40 on September 15, 2007.

8.1.5.6. *In the course of the year websites* http://Hg-Pavlodar.narod.ru и http://Hg-Kazakhstan.narod.ru *were being updated a few times* (section 13 of this report) containing information about the progress of demecurization and post-demercurization monitoring in the Northern industrial area of Pavlodar. The first website has already existed for 4 years and has in average 1000 visits per year. The second website has already existed for 2 years and has in average 500 visits per year. Creation of English version of both websites has increased the number of visits there in 2007 and expanded substantially the geography of these visits. PSU teachers use these websites widely as training aids.

8.1.5.7. During the year *negotiations were carried on with specialists and officials from Czech Republic, UK and Canada* (also visit to the Northern industrial area of cleaning from mercury was arranged) *about possibility to fund the research continuing ISTC K-1240p project*. Two proposals were prepared which were submitted to Czech (together with JSC GEOtestBRNO, Brno, Czech Republic) and UK (together with Oxford University) governments. Together with scientists from Russia (Dr. Faina Ingel and Prof. Mikhail Shpirt) two pre-proposals were prepared on study of mercury health effect in Pavlodar and contribution of Kazakhstani coal combustion to mercury emission to atmosphere. The data on groundwater mercury contamination in Pavlodar were given to Prof. Svetlana Abdrashitova for preparation of Work Plan of ISTC K-1477 project.

8.2. Technical progress during the first year of the project

8.2.1. Field works

Two expeditions were conducted at the Northern industrial area of Pavlodar: summer expedition – in March, 2007 (bottom sediments of the wastewater storage pond-Lake Balkyldak were investigated from under the ice) and autumn one – in September-October, 2007 (groundwater were investigated, the pond Balkyldak bottom sediments sampling was completed, gramma grass samples were taken across the pasture).

8.2.1.1. Investigation of groundwater

Groundwater investigation has been carried out across all area of the Northern industrial area of Pavlodar in order to obtain data about seasonal variation of their level and then to use this material for simulation of hydro-geological conditions and also in places of mercury contamination with purpose to receive the data on total mercury concentration changes.

8.2.1.1.1. Groundwater level measurements

In September, 2007 groundwater level measurements were taken in 154 observation boreholes. The procedure of the measurements was described in the first annual report. The results of the measurements ("Summery table 01.2006") as well as similar data of previous years have been used for calibration of the computer model of groundwater mercury contamination.

8.2.1.1.2. Groundwater sampling for their analysis for total mercury content.

Groundwater samples were taken from 81 observation boreholes of the system of mercury monitoring at the Northern industrial area of Pavlodar using a submerged electrical pump in September – October, 2007. The special sampling technique applied is described in the first annual report.
Not later than 4 hours after the sampling all water samples and blanks were delivered to analytical lab inside an ice-box so that their temperature was not higher than 10^{o}C.

8.2.1.2. Investigation of gramma grass mercury contamination

Gramma grass sampling for its analysis for mercury contamination were done across the pastures for private livestock belonging to inhabitants of Pavlodarskoe village. The pastures were located between the industrial site #1 of PCP and the wastewater storage pond Balkyldak. In September, 2007 two integral samples with wet mass of about 1 kg each were taken from two spots 10 m^2 each. The grass was dried in a dry not heated room and delivered to analytical lab in Almaty.

8.2.1.3. Investigation of mercury pollution of wastewater storage pond – Lake Balkyldak

Investigation of mercury pollution of wastewater storage pond – Lake Balkyldak lay in investigation of bottom sediments of the lake and its biota.

8.2.1.3.1. Estimation of bottom sediments mercury pollution of wastewater storage pond – Lake Balkyldak

Winter field works was conducted in March 2007 which continued the investigation according to the Sampling Plan on 200 sampling points. The sampling procedure was the same as in March, 2006 and described in the first annual report. 159 bottom sediment samples were taken from under the ice from 94 sampling points according to the regular grid. The samples were delivered to Almaty in frozen state in the beginning of April and prepared for determination of total mercury content similar to the samples collected in 2006.

In September, 2007 along the coastline of the lake 35 samples of bottom sediments were taken from 35 sampling point which remained untested from the Sampling Plan on 200 sampling points. These sampling points were inaccessible both in winter season (because of freezing the water down to the bottom) and from a boat in summer time due to thick reed thickets. The sampler wore a special waterproof costume and went cautiously to the sampling point from the shore. The samples were frozen and delivered to AIPET Laboratory in Almaty where were prepared for total mercury determination similar to other samples.

Bathymetric measurements and measurements of soft sediments thickness were carried out ("Summary table 04 and 05.2007) simultaneously with bottom sediment sampling and used to develop GIS of the Northern industrial area of Pavlodar.

8.2.1.3.2. Sampling of biota of the wastewater storage pond Balkyldak and the control pond.

Summer sampling of hydrobionts of both the pond Balkyldak and the control water body – Lake Krivoe was conducted in May-September, 2007 from three sampling stations (fig.6, Annex 1) similar to that in 2006 (ISTC K-1240p project Annual report for the first year, section 8.2.1.3.2.).

The characteristics of the sampling stations at the wastewater storage pond – Lake Balkyldak:

The station 1:

It is sand beach of 200x25 m; the sand is fine; the thickness of the sand layer is a few cm underlined with silt-clay sediments of black color. From the south, from PCP side there is a stream running out of concrete well and entering the wastewater pond. According to organoleptik evaluation the water is clean, without unusual smell, clear.

There are bituminous stains of different size all over the beach as well as separate heaps of old bitumen. The dam 2.5 m high made of packed clay with side slope of 60^{o} divides the wastewater storage pond Balkyldak and special ponds for mercury wastes which have turned into a landfill covered with multilayer screen the upper layer of which is turfy soil. Meadow grasses, reed thickets up to 40-60 m high grow here. Only here narrow-leaved reed mace is to be found. Also salt-resistant plants can be met sparsely here. At the station the most numerous gathering of birds (gulls, gooses, ducks, and swans) is observed. At the station 1 plankton organisms and near-water invertebrates were sampled. Empty shells of shellfish can be met. Herd of livestock uses this part of the pond Balkyldak as a watering place and surface of the landfill - as a pasture.

The station 2:

The shore of the wastewater storage pond Balkyldak is strengthened with man-made dam covered with concrete slabs. The dam is 2.5-3 m far from the shore line. Reed plants come up to the shore in some places. The station 2 is the favorite place for fishermen who catch fish there mostly using fishing rods and sometimes – fishing nets. Silver crucian is main catch here.
State of the near-shore zone is determined with practically permanent presence of a man. There are numerous quantities of different things: mainly plastic bottles there. So lots of litter at the near-shore zone plays positive role for many of small organisms – it is right place to find large quantity of invertebrates. There are too much less birds, however sometimes one can see gulls, ducks and cranes there, also gophers live in the dam.

There were taken: silver crucian – 86 samples (including 30 samples for morphological analysis and 56 samples for chemical analysis); carp – 1 sample (for chemical analysis); shellfish, benthos and plankton – 1, 4 and 2 samples respectively for both chemical analysis for total mercury content and morphological analysis.

The station 3:

It is sand beach of 100x15 m; the sand is coarse. Here in winter time a foam roller 1 m wide is formed along the coast line with color spectrum from white to dirty-brown. The foam is soapy by touch. The water is without any foul or strong odor. The shore is strengthened with man-made dam covered with crashed stone. The dam is 2-2.5 m far from the shore line. There are predominantly meadow plants, saltwort, and reed thickets up to 40-60 m high within the territory bounded with the dam. Ornitho-fauna is represented by gulls, wagtails, and ducks. One can see a lizard at the shore. There are no living shellfish over the shore – only their empty clean shells that are not met at all in other places. This part of the lake is used by fishermen for fishing by rods or nets and the shore – as a watering place for horses which pasture over the area adjacent to the pond.

There were taken: fish (silver crucian) – 60 samples from the wastewater storage pond Balkyldak and 30 samples from the pond Krivoe (separately a few mass measurements of fish were taken for their morphological analysis); benthos and plankton – 8 and 9 samples from Balkyldak: benthos organisms – 3 samples from Lake Balkyldak water catchment area and 3 samples from the control pond Krivoe.

Samples for their chemical analysis for mercury were frozen and delivered to AIPET Laboratory in Almaty.

8.2.2. Chemical analytical works

8.2.2.1. Groundwater analysis for total mercury content was conducted in a laboratory room at the territory of the former PO "Khimprom" provided by JSC "Kaustik". Analytical equipment brought from Almaty was used. Other chemical and analytical works were carried out in AIPET laboratory in Almaty. All operations on sample preparation and analysis were done similar to methods used in 2006 that were described in the first annual report on the project.

81 groundwater and 111 soil samples were analyzed for total mercury content.

The results of analyses of groundwater and soil samples were used for the database producing ("Summary tables 02.2007 and 03.2007").

8.2.2.2. Laboratory experiment on determination of coefficients of mercury adsorption for hydro-geological simulation lay in determining mercury (II) chloride in aquatic solutions which were in equilibrium with loamy sand taken during drilling observation hydro-geological borehole in the Northern industrial area of Pavlodar in 2002. Mercury concentration in groundwater taken from the same borehole at the same time was lower than 50 ng/l.

2 g of loamy sand sifted through a plastic 2 mm mesh sieve were placed in 36 one-use tightly closed test-tubes with volume of 25 ml (newly-made preforms of polyethylene tetraphthalate (PET) for production of coca-cola bottles with screw-tops of the same material were used as test-tubes). All of these test-tubes were filled with 20 ml of 0.33% NaCl containing different concentrations of $HgCl_2$: 0; 6.65; 13.3; 33.0; 66.5; 100; 133; 200; 266; 665; 1330; 2660; 6650; 13300; 33000; 66500; 100000; 133000 μg/l. Each of 18 experiments was duplicated (in total it was 36 experiments), besides third set of 18 test-tubes was used for blank experiments with the same solutions of NaCl и $HgCl_2$, but not containing loamy sand. All solutions were prepared on reagent water which was used when analyzing mercury in natural waters (The first annual report on ISTC K-1240p project, section 8.2.2.). Test-tubes were closed with screw-tops, placed into a shaker and shaken for 6 hours at a speed of 200 min^{-1} and the temperature of 15 ^{0}C.

After shaking the solution and loamy sand mixtures out of every test-tube (for blanks it was only solutions) were filtered under the pressure through membrane filter with pore size of 0.45 mkm into one-use Coca-Cola bottles. The filtrates were diluted with 0.6 M HCl up to 0.5 l, then digested with bromide-bromate mixture and analyzed using spectrometer "Millennium Merlin" similar to natural water samples analyzed for mercury (The first annual report on ISTC K-1240p project, section 8.2.2.).

The results of mercury determination in $HgCl_2$ in the blank experiments were used as amendments for taking into account mercury absorption by walls of vials and equipment used.

Based on the obtained results the diagram for Freundlich adsorption isotherms was constructed. The diagram consisted of two linear parts with its break at mercury concentration of 200 μg in initial solution. The left part of the diagram had a slope ratio close to the unity. It meant that obtained dependence was close to Henry isotherm at mercury content less than 200 μg in the initial solution. Since groundwater in the Northern industrial area contain mercury less than 200 μg it turned out to be possible to use Henry adsorption isotherms for producing computer hydro-geological model of the groundwater mercury contamination using a distribution coefficient of **0.04 l/mg** calculated on the basis of the laboratory experiment.

8.2.3. Office study

8.2.3.1. Database creation

Computer summary tables (Summary tables 01-07.2007) were compiled based on the results of field measurements and chemical and analytical works to form the database of post-demercurization monitoring. Due to its huge size the database is not presented in ISTC K-1240p project reports.

8.2.3.2. Analysis of the results of investigation of groundwater mercury contamination

The results of determination of mercury concentration in groundwater at the area of mercury pollution ("Summary table 02.2007) were inserted onto the vector map together with the results of similar research of 2004, 2005 and 2006 (fig.2, Annex 1) similarly to that in the first annual report on ISTC K-1240p project, section 8.2.3.3.. Together with Table 1 (Annex 1) this map shows dynamic of total mercury concentration change in groundwater within the plume of contamination in post-demercurization period and allows finding spots with increase in mercury concentration at the area of groundwater mercury contamination plume. Continued decrease in mercury concentration levels as well as shrinking of the area of the contamination to the west from the cut-off wall around the former electrolysis factory (building 31) is evidence of efficiency of the taken engineering solutions on isolation of the source of mercury contamination located under the former building 31 from groundwater. However the field works conducted in 2006 and 2007 show that at the same time high levels of mercury contamination of groundwater to the north from the cut-off wall are still the same. Most likely that results from infiltration of both atmospheric precipitation and melt water through the topsoil still heavily contaminated with metallic mercury (the first annual report on ISTC K-1240p project, section 8.2.3.4.). If this assumption is true the fact of permanent high mercury concentration in the groundwater proves the conclusion about high residual risk posed by topsoil mercury contamination at the industrial site of former chlor-alkali production (the first annual report on ISTC K-1240p project, section 8.2.3.4.). It proves the topicality of conducting additional works on mapping and soil cleaning at the industrial site #1.

In 2007 high mercury concentrations was also revealed to have appeared in the boreholes 73-02 and 79-02 where mercury was not found at all before though (table 1, Annex 1). This result conforms very well to results of simulation of groundwater mercury contamination development, obtained in 2007 using the local model (section 8.2.4.) and testifies for continued spread of the plum of groundwater mercury contamination to the north-west direction.

8.2.3.3. Analysis of the results of investigation of soil mercury contamination

The results of determination of mercury concentration in soil samples taken on the regular grid within the industrial site #1 and the wastewater storage pond Balkyldak ("Summary table 03.2007) were used for correction of the map of the soil mercury contamination produced in 2002 (fig.1, Annex 1). At the result of the correction the vast area of topsoil mercury contamination was designated on the map to the north from the former 6th wastewater pumping station formed by either mercury contaminated groundwater rise up to the ground surface (section 8.2.4. of this report) or leakage from drainage system. Boundaries of this area have to be determined more precisely by additional soil sampling as it is envisaged in the Sampling Plan (section 8.1.3. of this report and fig.3-5, Annex 1). Confirmation of the assumption about mercury contaminated groundwater rise as a reason of topsoil mercury contamination proves in turn high degree of risk still posed by the plum of groundwater mercury contamination because the area of topsoil mercury contamination was found within the pasture for livestock belonging to inhabitants of Pavlodarskoe village.

8.2.3.5. Analysis of the results of investigation of biota.

The list of aquatic fauna of the wastewater storage pond was drawn up:

INVERTEBRATES
The aquatic invertebrates are presented with background hydro-bionts among which the followings predominate:

Class ROTIFERA - Rotatoria
Species Brachionidae
Keratella sp.
Species Asplanchnidae
Asplanchna sp.
Species Trichocercidae
Trichocerca sp.
Species Synchaetidae
Synchaeta sp.
Species Brachionidae
Brachionus sp.
Species Filiniidae
Filinia sp.
Species Conochilidae
Conochilus sp.

Class OLIGOCHAETA
Species Naididae
Nais sp.
Chaetogaster sp.
Species Tubificidae
Tubifex sp.
Limnodrilus sp.
Potamothrix sp.

In near-shore zone the following grope of organisms can be met among macrophyt thickets:
Species Chrysomelidae
Chrysolina aurichalcea
Chrysochus goniostoma

Galeruca tanaceti
Galeruca interrupta circumdata

Species Meloidae

Mylabris guadripunctata

Species Carabidadae

Cicindela campestris
Pterostichus sp.
Anisodactylus signatus

Hydro-bionts of littoral zone are generally presented by shellfish:

Species Dycidedae

Coelambus sp.
Laccophilus hyalinus
Noterus crassicoris

Species Gyrinidae

Gyrinus minutus

CLASS - GASTROPODA
Order - Hygrophila
Species Lymnaeidae

Lymnaea auricularia
Lymnaea kazakensis
Lymnaea fragilis
Lymnaea fontinalis
Lymnaea ampullacea
Lymnaea lagotis

ICHTIOFAUNA

According to the control haul Carassius auratus gibelio, Cyprinus carpio aralensis Spitshakov and Tinca tinca inhabit in the wastewater storage pond Balkyldak. Carassius auratus gibelio predominates in hauls.

In the pond Balkyldak shellfish inhabit exclusively spring mouths. Living shellfish as well as their shells have not been found within water area of the very lake. It testifies for considerable toxicity of the lake water for representatives of spineless. Study of shellfish of different size and age shows that their shells have undergone great changes. The capsules structure is transformed: some sort of convexity, roughness, deformation especially in ostium part that was not found at shellfish from "clean" water bodies.

Comparison of species composition of shellfish in the Irtysh River basin and the pond Balkyldak suggests considerable difference in species variety. Only two shellfish species belong to both systems. Evidently aquatic environment of the wastewater pond is unfavorable habitat for many shellfish species.

8.2.4. Computer simulation

Calibration of the local model of hydro-geological conditions in the Northern industrial area of Pavlodar has been completed for the site of groundwater mercury contamination.

Analyses of the character of the hydro-geological conditions of the investigated area as well as the results of the modeling have been implemented to estimate possible soil mercury contamination as a result of contaminated groundwater rise up to the ground surface followed by their evaporation. Spatial relation of the regional model of hydro-geological conditions in the Northern industrial area of Pavlodar and the local model of the site of groundwater mercury contamination is shown on fig.8, Annex 1. Water-bearing rocks with different filtration properties are designated by colors on the cross section.

While producing the local model reproduction of detailed lithological structure of the investigated area was required (fig.9, Annex 1).

Quality of the local model calibration was evaluated according to degree of its conformity to existing natural conditions taking into account the results from the regional model. The calibration involved solution of a series of inverse tasks: stationary and non-stationary hydro-dynamic ones as well as the task on mercury transport by groundwater flow.

When solving inverse stationary hydro-dynamic task position of groundwater levels as of 1970 i.e. conditionally undisturbed period was reproduced in the model. Solution of the inverse non-stationary hydro-dynamic task on the model simulated the change in groundwater table surface from 1970 to 2006. Specific yield was established as 0.22. Specific storage of water-bearing rocks was equal to 0.001 1/m. Maximal value of groundwater recharge due to losses from engineering services achieved 0.002 m/day. Boundary conditions were established by interpolation of the local model solution obtained on the regional model into boundary blocks (fig.10, Annex 1).

Inverse transport task (for the period from 1975 to 2006) was solved for simulation of the process of mercury transport by groundwater flow. Advective component of the substance flow was calculated based on solving the hydro-dynamic task. Mercury adsorption by water-bearing rocks was reproduced on the local model. Equilibrium between liquid and solid phases was assumed to attain immediately. The linear isotherm Henry (the model of irreversible equilibrium sorption) was used to describe the process of dissolved mercury adsorption:

$$\overline{C} = K_d C ,$$

where $\overline{C}$ [MM^{-1}] – sorbed concentration, C [M/L^3] – dissolved concentration, K_d [L^3M^{-1}] – distribution coefficient.

Based on the results of laboratory experiments on mercury adsorption by loamy sand taken from the area of contamination (section 8.2.2.2.) the Henry constant was assumed to range from 0.01 to 0.04 l/mg for clay material and from 0.00001 l/mg for different-size grained sand to 0.0015 l/mg for clay and dust sands. Porosity of clay material was assumed to be 0.3, sand one – 0.22. Dissolved mercury concentration in groundwater closed to hotspots of soil mercury contamination ranged from 0.5 to 0.04 mg/l. High degree of precision coincidence of calculated values of both groundwater tables and mercury concentrations with values obtained as a results of field trials suggests adequacy of the detailed local model to existing natural conditions (fig.11, Annex 1).

Within the area being simulated water-bearing rocks are presented by sands interlaced irregularly with clay and loam. Mercury can not go even through thin clay interlayers but it can be adsorbed by their surface. Based on the results of modeling mercury transport was found to occur not only horizontally through sand between clay interlayers but also in vertical bottom-up direction through so called “windows” in places of clay interlayers pinching-out. It allows making up a conclusion about existence of spots where mercury can get to zone of aeration and then to plants and surface water. The results coming from the model require to be verified by the results of field trials. Finding the spots of mercury getting to zone of aeration required additional analysis of both character of hydro-geological conditions within the area of investigation and the results of modeling. For that 13 more precise hydro-geological cross sections were constructed within the area of mercury contamination spread on the basis of source hydro-geological information being in databases. The map produced on the basis of the material available and four main cross sections are shown on fig.12-16, Annex 1. These cross sections along with the results of solution on the local model of different scenarios of prognosis tasks underlay the area zoning (according to groundwater table occurrence depth, mercury concentration in groundwater and the character of lithological structure). To carry out zoning the maps of lithological structure were used, where there were taken into account following factors: spots not having clay in the top of a cross section, distribution of mercury concentration in groundwater at different points of time, depth of groundwater table occurrence marking the depths less than critical one. Value of critical depth (i.e. the depth from which groundwater evaporation starts) was established as 2.4 m based on earlier field studies. Thus zones were revealed where mercury contaminated groundwater can rise up to lower boundary of aeration (fig.17, Annex 1). Three-dimensional diagram of the plum of groundwater mercury pollution spread based on the results of modeling as of the end of 2006 is presented on fig.18, Annex 1.

9. Current technical status of the project

In general the works have been conducted in compliance with the Work Plan. Unfortunately inflation and slow replacement of Participant Institution PCP by Kaustik made very difficult conducting field works in autumn, 2007.

Correction of the Task 3 of the Work Plan on replacement of scheduled oil product monitoring by mercury monitoring have been approved by the Partners and Pavlodar Oblast Territorial Department of Environment Protection.

10. Cooperation with foreign collaborators

During the second year of K-1240p project there were two meetings with the Partner Paul Randall (one - in Southampton, UK, February, 2007 and another – in Pavlodar and Almaty, Kazakhstan, September, 2007) and also one meeting with the Collaborator Trevor Tanton (together with Paul Randall in Southampton, UK, February, 2007). In the course of the joint meeting the correction of K-1240p project Work Plan, the project progress, methods of works and results obtained were being discussed. In Pavlodar Paul Randall participated in field works and shared his experience in sampling.

Joint attendance to conferences and workshops:

With Paul Randall and Trevor Tanton:
Workshop “Biomercury” in Southampton University (Southampton, United Kingdom, 19-23 February, 2007).

11. Problems encountered and suggestions to remedy

Main problems of the second year arose from bad involvement of two Kazakhstani Participant Institutions in K-1240 project work: PCP – because of bankruptcy of the enterprise and protracted procedure of replacement of this Participant Institution by Kaustik, and BMP – due to reorganization of Stepnogorsk Laboratory of Monitoring and replacement of its manager Serzhan B. Amanov. Correction of the financial part of the project necessary to conduct the reorganization took lots of time and efforts. Besides approval of replacement of works on oil product monitoring in the project Work Plan took great efforts as well.

Arrangement and holding the International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007) took additional efforts from AIPET team and resulted in delay in preparing Quarter reports. However in autumn this delay was overcome.

12. Perspectives of future developments of the research developed

The results of the second year project works showed insufficiency of funding for monitoring research only through ISTC to estimate the current status of mercury pollution in Pavlodar and plan further pollution management. Without the local financing the conducted works will be stopped after completion of K-1240p project despite the great interest to them from local people and foreign specialists. At that there is danger that acquired and applied for field and laboratory works equipment, skills and experience of specialists as well as collected materials will be lost irreparably.

The time remained until K-1240 project ending must be generally used for creation of *Regional Monitoring Research Center* at the territory of a former PO “Khimprom”, Pavlodar and finding a stable source of its funding. Conducting monitoring works at the cost of foreign grants becomes unpromising due to high rate of dollar inflation in Kazakhstan and unprecedented services and manpower cost increase.

13. List of papers and reports published

1. S.M.Ullrich, M.A.Ilyushchenko, I.M.Kamberov, T.W.Tanton. Mercury contamination in the vicinity of a derelict chlor-alkali plant. Part I: Sediment and water contamination of Lake Balkyldak and the River Irtysh. The Science of the Total Environment, V. 381, 2007, P. 1-16

2. S.M.Ullrich, M.A.Ilyushchenko, T.W.Tanton, G.A.Uskov. Mercury contamination in the vicinity of a derelict chlor-alkali plant. Part II: Contamination of the aquatic and terrestrial food chain and potential risks to the local population. The Science of the Total Environment, V. 381, 2007, P. 290-306

3. M.A.Ilyushchenko, L.V. Yakovleva (editors). Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, 99 p.

4. M.A.Ilyushchenko. Problems of demercurization of industrial objects within the former USSR Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 15.

5. A.D. Akhmetov, V.A.Bednenko. Experience of demercurization works within the territory of former PO “Khimprom”, Pavlodar. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 18.

6. V.Yu. Panichkin. Risk assessment from groundwater mercury pollution of the Northern area of Pavlodar industrial region by the methods of mathematical modeling. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 20.

7. O.L. Miroshnichenko. Methods and technology of creation of the system of mathematical models with different scales for groundwater mercury pollution within the industrial area of

Pavlodar city. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 21.

8. M.A. Ilyushchenko, R.I. Kamberov, L.V. Yakovleva. Post-demercurization monitoring and risk assessment in the Northern industrial area of Pavlodar city. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 23.

9. S.A. Abdrashitova, W. Davis-Hoover, R. Devereux. Development of technology of bioremediation of mercury contaminated groundwater for Pavlodar outskirt. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 24.

10. V. Ye. Khrapunov, B. L. Levintov, S. A. Trebukhov. Development of integrated demercurization technology and facilities for its implementation in Kazakhstan. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 25.

11. F.I. Ingel, J. Eyless, P. Eckl, M. Chiba, S.N. Khussainova. Risk assessment of human health under exposure with low-level of mercury. Proceedings of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects” (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 42.

12. Website http://Hg-Pavlodar.narod.ru has been updated: a section has been introduced relating to ISTC K-1240 project; the section “Mercury pollution management and its monitoring in Pavlodar city, the Republic of Kazakhstan” has been expanded; English edition of the website has been created; and illustrations have been added.

13. Website http://Hg-Kazakhstan.narod.ru has been updated: a section has been introduced containing materials of International Workshop “Environmental mercury pollution: mercury emissions, remediation and health effects”, Astana, Kazakhstan (May 28 – June 1, 2007).

ANNEX 1: Illustrations attached to the main text

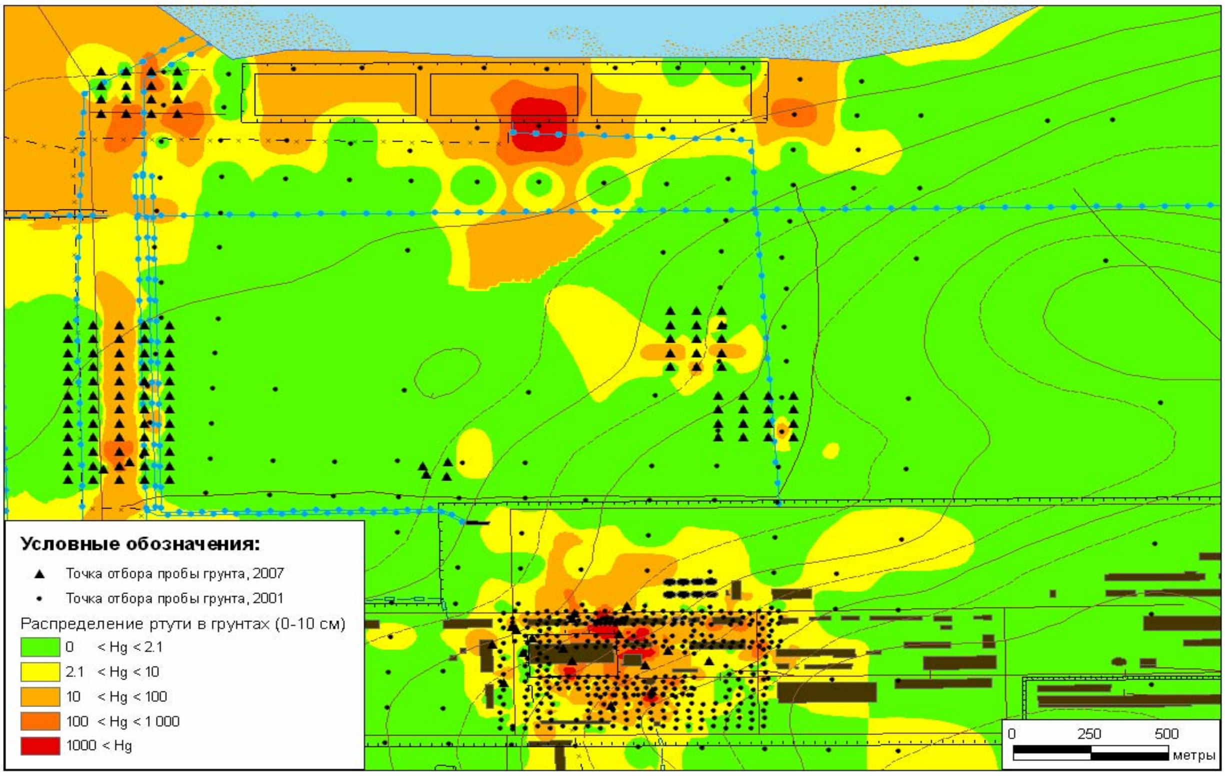

Fig.1. Map of soil mercury contamination (topsoil 0-10 cm) in Northern industrial area, Pavlodar completed with data of 2007 on 111 sampling points.

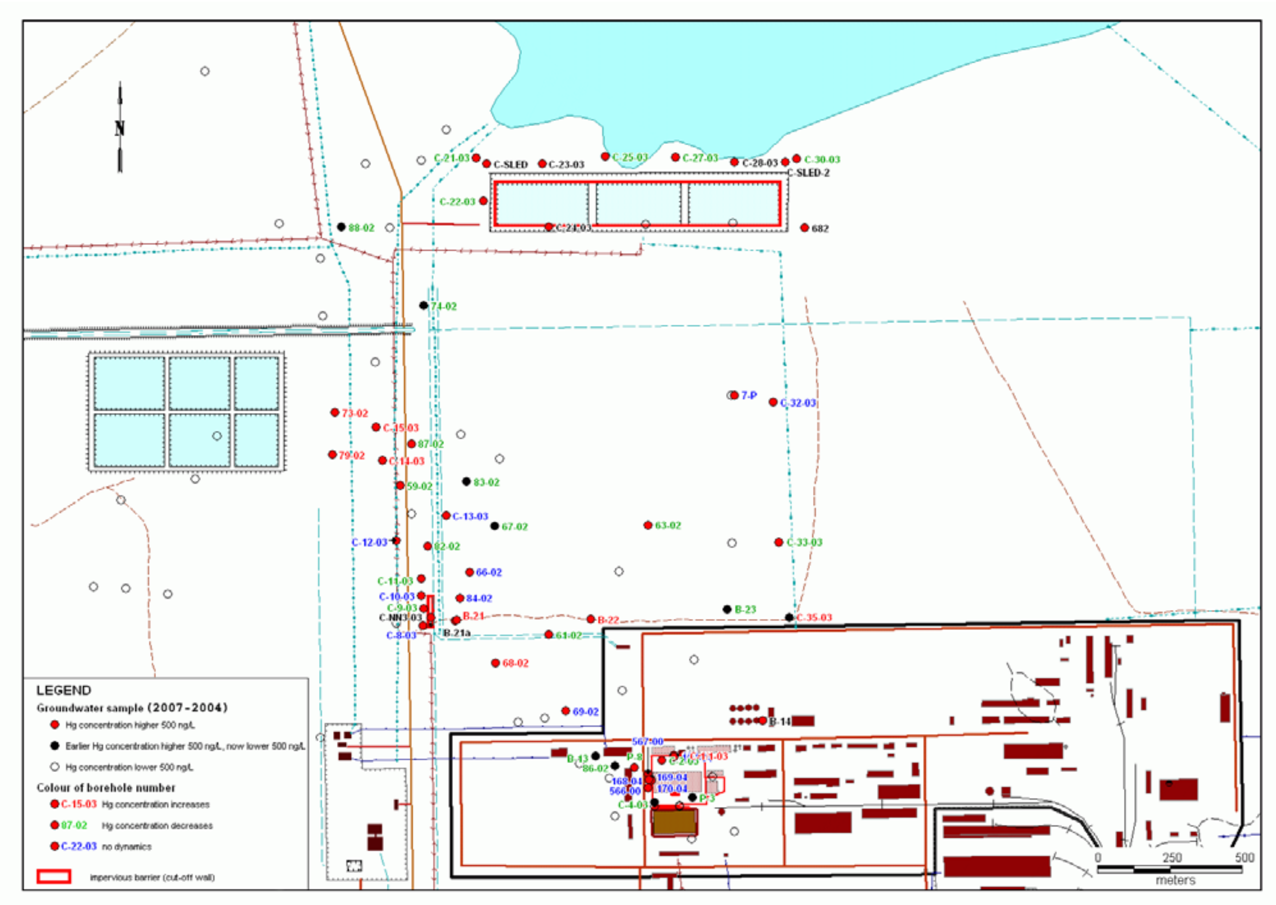

Fig.2. Dynamic of total mercury concentration change in groundwater of the Northern industrial area, Pavlodar in 2004-2007

Table 1

Dynamic of total mercury concentration change in groundwater of the Northern industrial area, Pavlodar (on the results of mercury monitoring of 2004-2007)

NN	Borehole name	Total mercury concentration, ng/l 2004	Total mercury concentration, ng/l 2005	Total mercury concentration, ng/l 2006	Total mercury concentration, ng/l 2007
1	C-16-03	129		144	121
2	C-17-03	223		171	71.2
3	C-18-03	36		46	42.3
4	C-19-03	175		229	98.1
5	C-20-03	97		140	83
6	**C-21-03**	4425		1630	734
7	**C-SLED**	3195		not able to pump	not able to pump
8	**C-22-03**	1400		1200	593
9	**C-24-03**	2995		not able to pump	not able to pump
10	C-26-03	19		not able to pump	not able to pump
11	C-29-03	58		not able to pump	not able to pump
12	**C-30-03**	45250		23500	19100
13	**C-SLED-2**	90650		not able to pump	not able to pump
14	**C-28-03**	5390		not able to pump	not able to pump
15	**C-23-03**	648		not able to pump	not able to pump
16	**C-25-03**	2455		2180	1160
17	**C-27-03**	24450		12500	11900
18	**C-15-03**	1625		11800	15000
19	**C-14-03**	2875		7450	12600
20	**C-13-03**	6175		4700	4080
21	**C-11-03**	29550		16400	7400
22	**C-12-03**	28850		31500	20600
23	**C-8-03**	35400		43500	38000
24	**C-9-03**	27200		17600	14400
25	**C-NN3-03**	6025		not able to pump	not able to pump
26	C-34-03	80		86	57
27	**C-35-03**	171		737	387
28	**C-33-03**	943		941	536
29	**C-32-03**	43850		40600	49300
30	**63-02**	5050		3950	3190
31	62-02	35		21	22.9
32	C-6-03	21		138	235
33	**84-02**	28850		30800	33600
34	**67-02**	854		493	439
35	**83-02**	798		493	445
36	72-02	69		44	31.9
37	90-02	140		140	74.2
38	**74-02**	1435		338	164
39	**87-02**	9315		6150	3990
40	70-02	105		307	232
41	**73-02**	479		744	763
42	**79-02**	126		919	2760
43	55-02	50		59	163
44	89-02	76		38	very low yield
45	**88-02**	468		504	262
46	**682**	3160		not able to pump	not able to pump
47	P-6	50		10	10.3
48	565-00	29		52	35.5
49	522-00	<5		<5	<5

50	78-02	32		111	86.6
51	81-02	14		9	13.8
52	**566-00**	3055		5100	2870
53	**86-02**	1775		287	104
54	85-02	6		<5	<5
55	P-1	23		83	56.3
56	6-P	39		29	32.1
57	5-P	12		<5	6.19
58	C-5-03	121		160	200
59	**C-4-03**	517		354	195
60	**P-3**	24700		14700	low yield
61	**C-2-03**	137000		36500	42700
62	**C-1/1-03**	2135		5600	3820
63	**B-22**	1255		4780	2240
64	8-P	<5		not able to pump	not able to pump
65	**7-P**	3875		2490	2810
66	**B-23**	946		442	440
67	C-1-03	212		not able to pump	not able to pump
68	**B-14**	4030		not able to pump	not able to pump
69	**B-13**	2845		724	215
70	P-4	159		72	28
71	75-02	166		364	273
72	76-02	8		<5	9.25
74	**61-02**	17600		5420	2260
75	**B-21**	12150		27300	33300
76	60-02	15		not able to pump	not able to pump
77	**C-10-03**	41300		39300	40900
78	**B-21a**	126000		destroyed	destroyed
79	**567-00**	47000		23400	48900
80	**P-8**	102750	18000	14200	14500
81	**82-02**	57550		44600	34500
82	**66-02**	85300		167000	108000
83	**59-02**	41100		32400	24900
84	**68-02**	36700		57200	65200
85	**69-02**	153500	165000	154000	137000
86	29-P	not observed		449	not able to pump
87	**165-04**	not observed		10500	8980
88	**166-04**	not observed		3380	2830
89	**167-04**	not observed		3310	2420
90	**169-04**	not observed		28200	32300
91	**170-04**	not observed		6880	7970
92	**168-04**	not observed		7220	7410
93	171-04	not observed		270	95.2
94	162-04	not observed		295	not able to pump
95	164-04	not observed		123	139
96	529	not observed		44	61.6
97	64-02	not observed		7	27.4
98	24-91 (93)	not observed		71	87
99	77-02	not observed		<5	9.49
100	23-91 (92)	not observed		11	21

Comments to the table 1: “Borehole name” column: red borehole names indicate increase in mercury concentration, green – decrease in mercury concentration, blue – absence of any dynamics; “Total mercury concentration” column: red figures indicate exceeding the sanitary standard (500 ng/l).

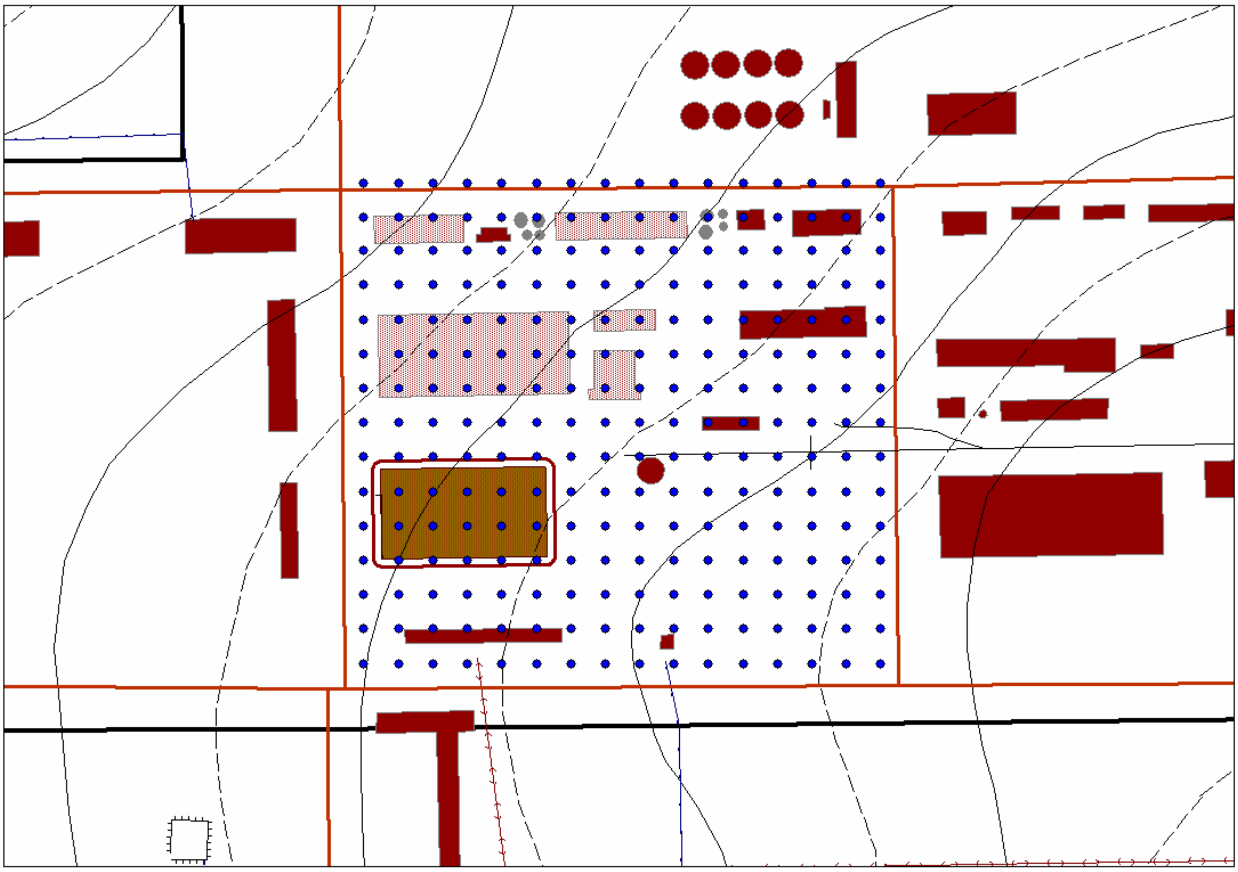

Fig. 3. Soil sampling plan from three layers: 0-10, 10-20, 20-50 cm deep at the area of a former chlor-alkali facility of PCP ("territory of demercurization")

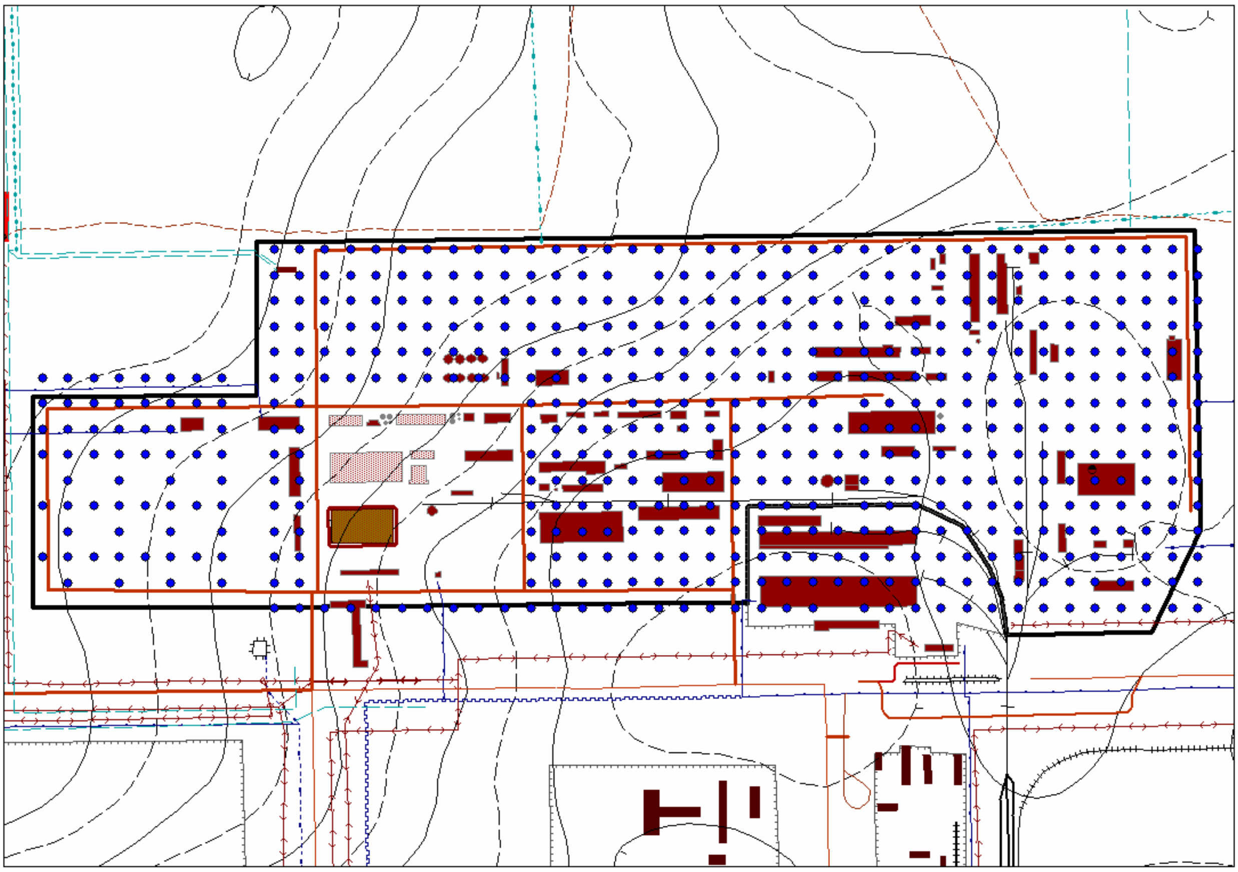

Fig. 4. Soil sampling plan from three layers: 0-10, 10-20, 20-50 cm deep at the area of industrial site # 1 of PCP

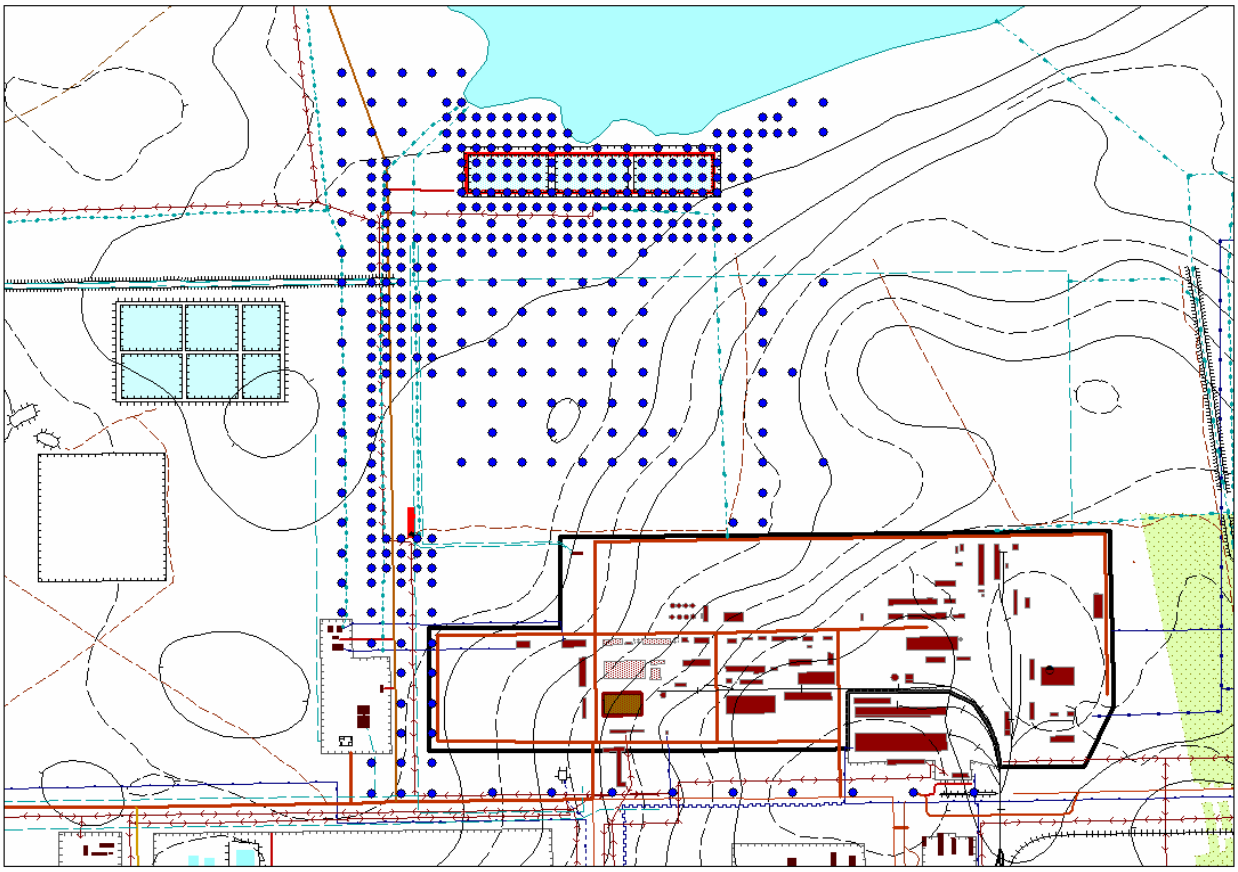

Fig. 5. Soil sampling plan from three layers: 0-10, 10-20, 20-50 cm deep at the territory around the industrial site # 1 of PCP

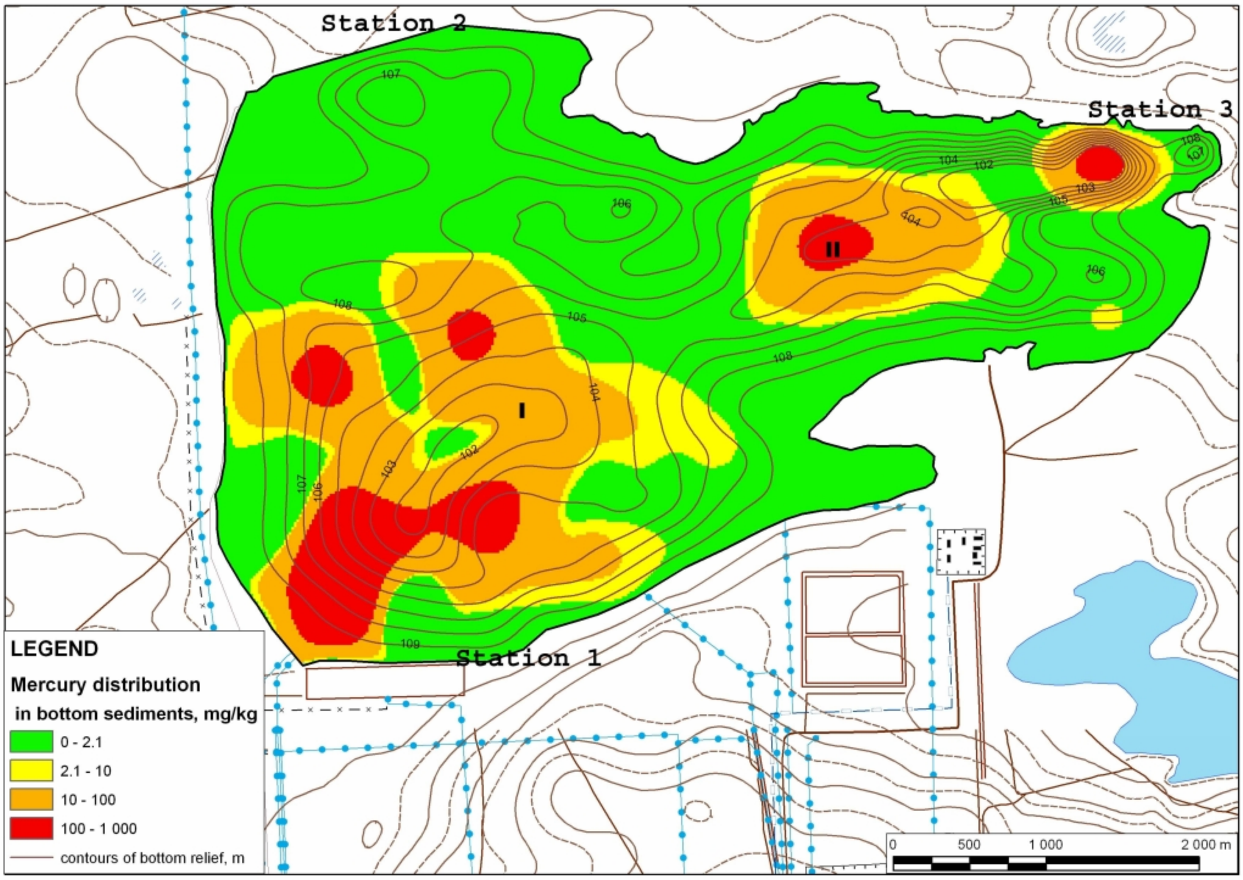

Fig. 6. Sampling stations for biota collection at the wastewater storage pond – Lake Balkyldak

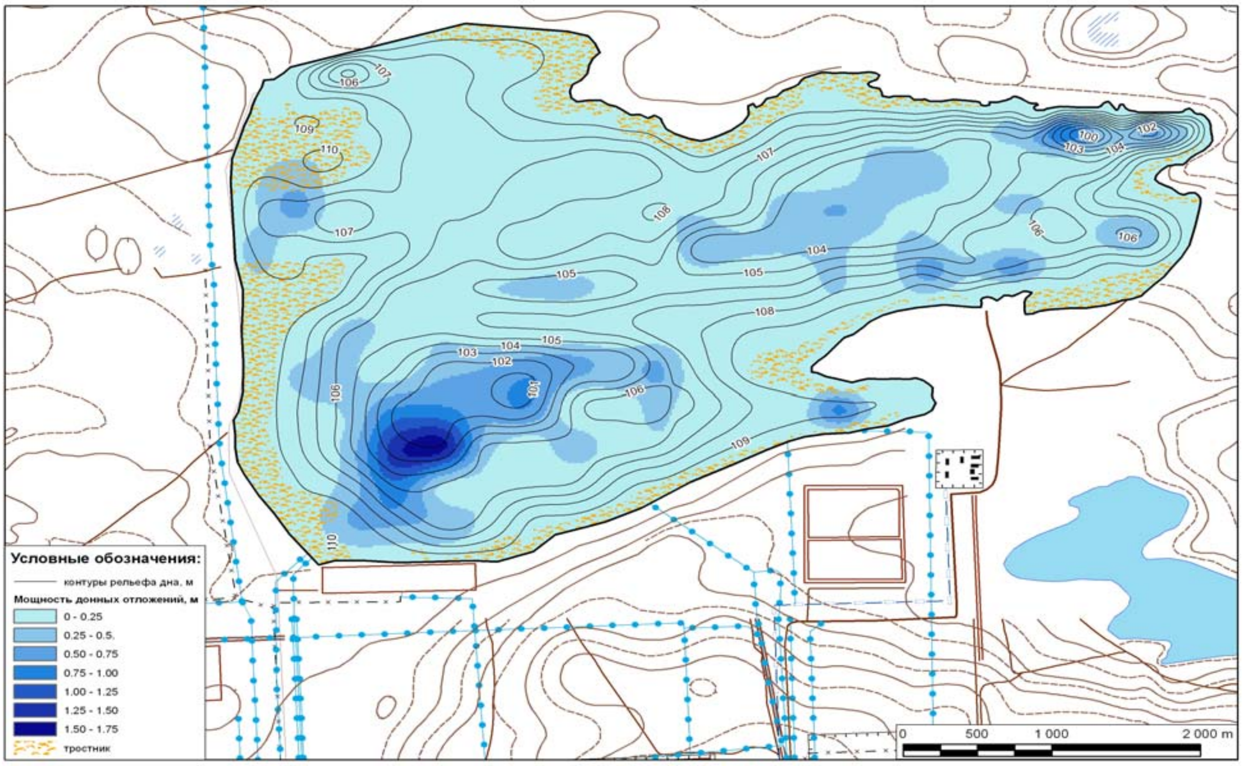

Fig.7. Map of depths and thickness of bottom sediments of wastewater storage pond – Lake Balkyldak

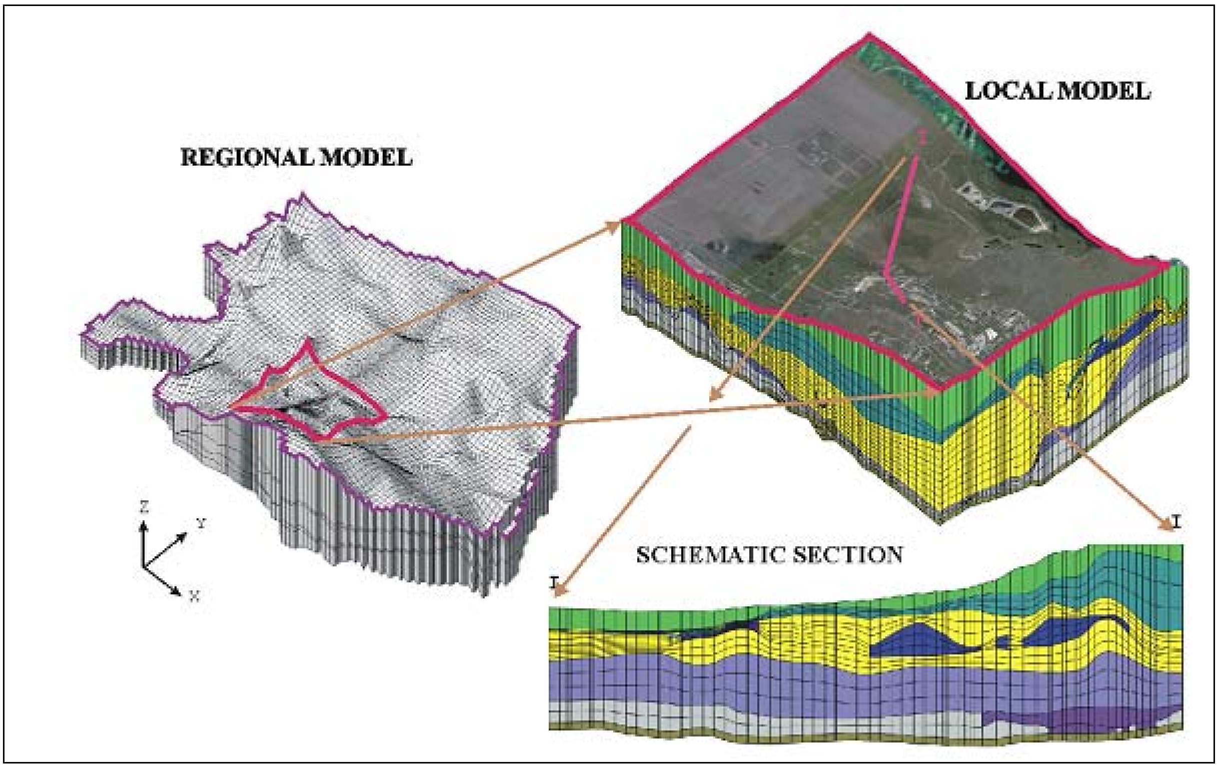

Fig. 8. Structure of system of models of hydro-geological conditions in the Northern industrial area of Pavlodar

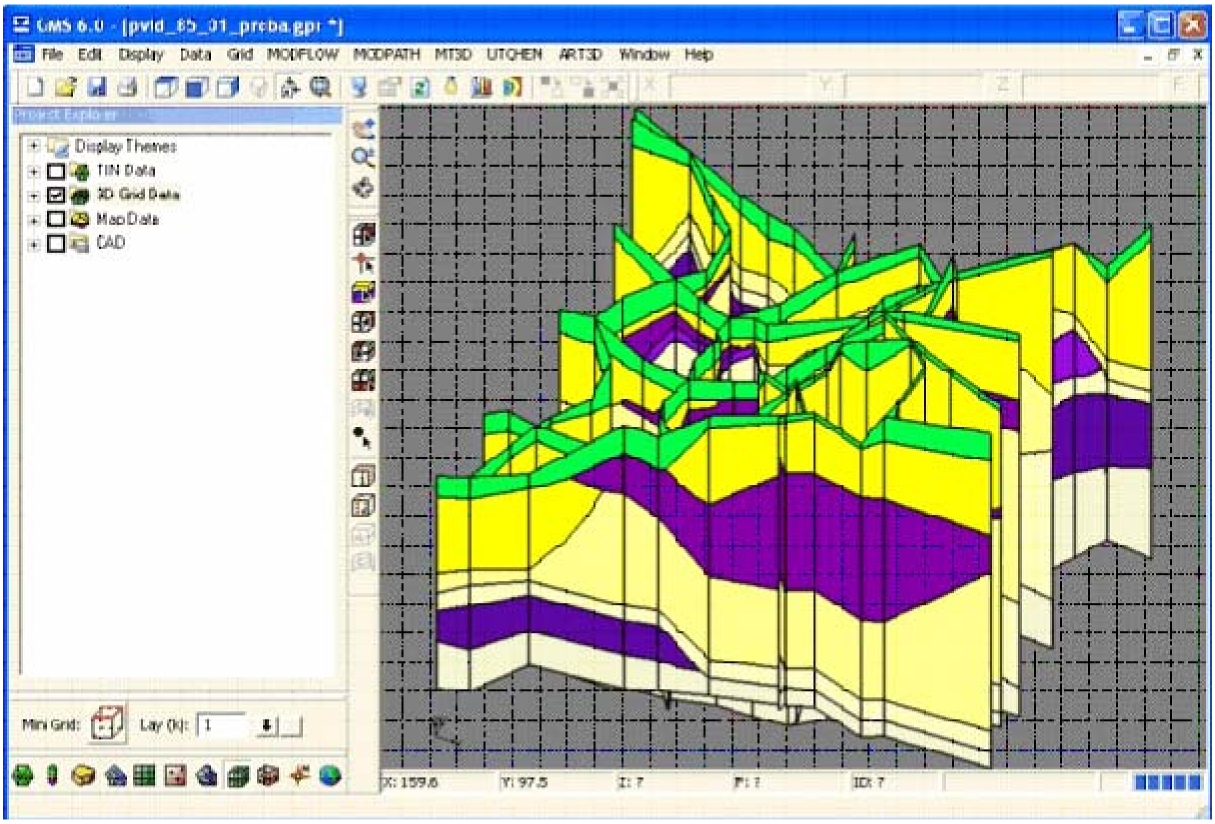

Fig. 9. Three-dimensional stratigraphy model

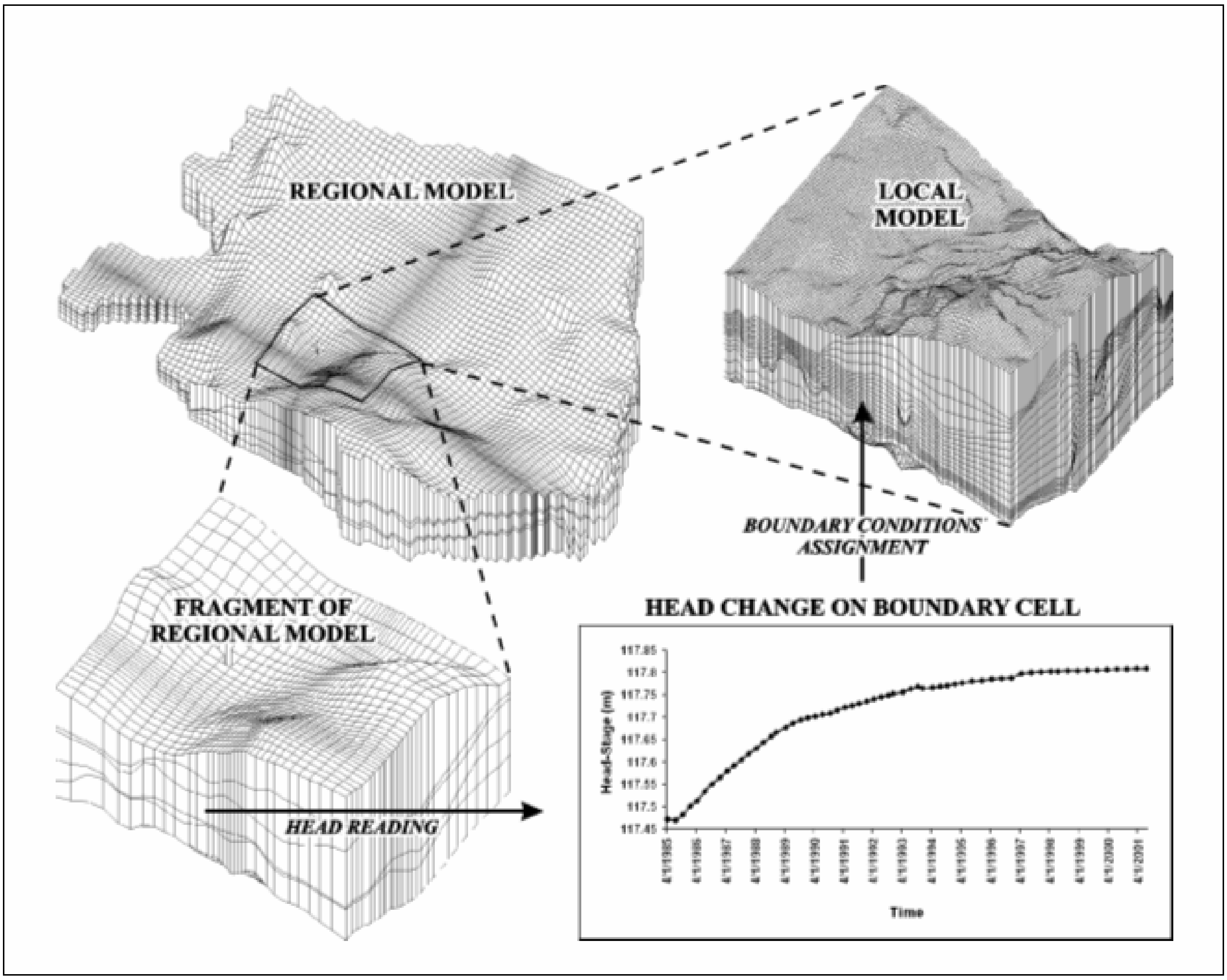

Fig. 10. Establishment of absolute groundwater marks on outer boundaries of local model

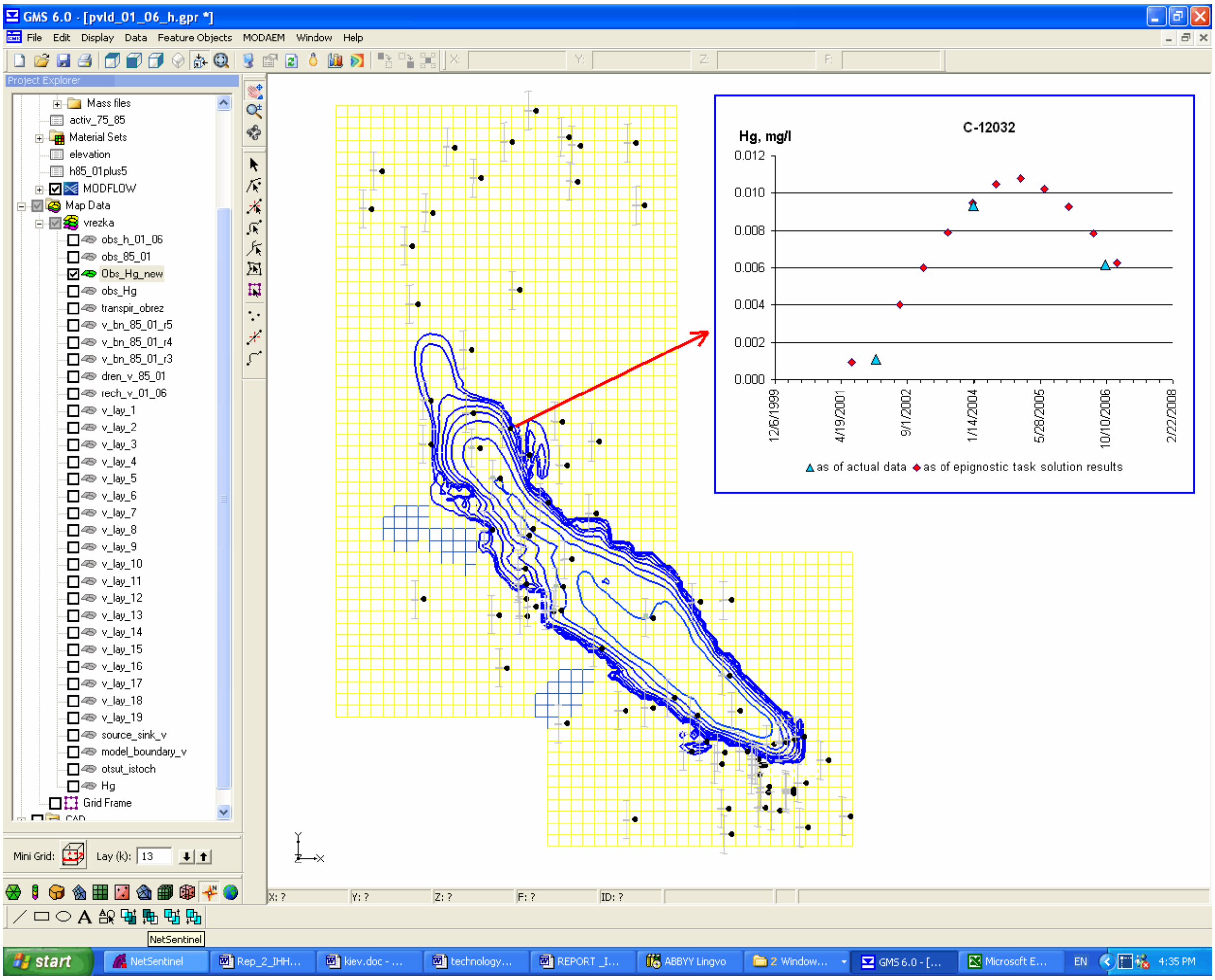

Fig. 11. Improvement of local hydro-geological model

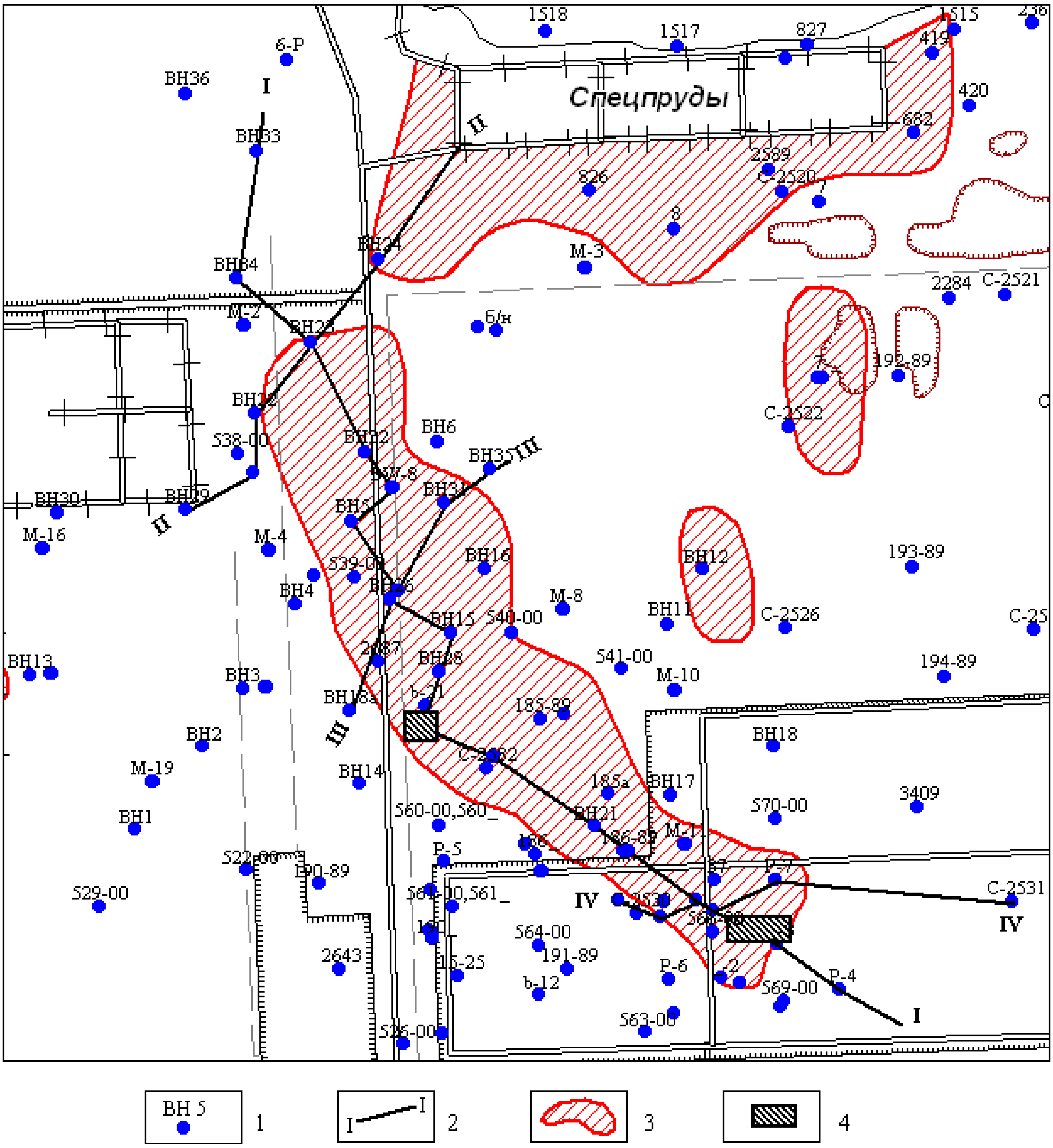

Fig. 12. The map produced on the basis of the material available

1 – hydro-geological boreholes and its name
2 – a line of hydro-geological cross section and its number
3 – groundwater mercury contaminated area
4 – main sources of mercury pollution

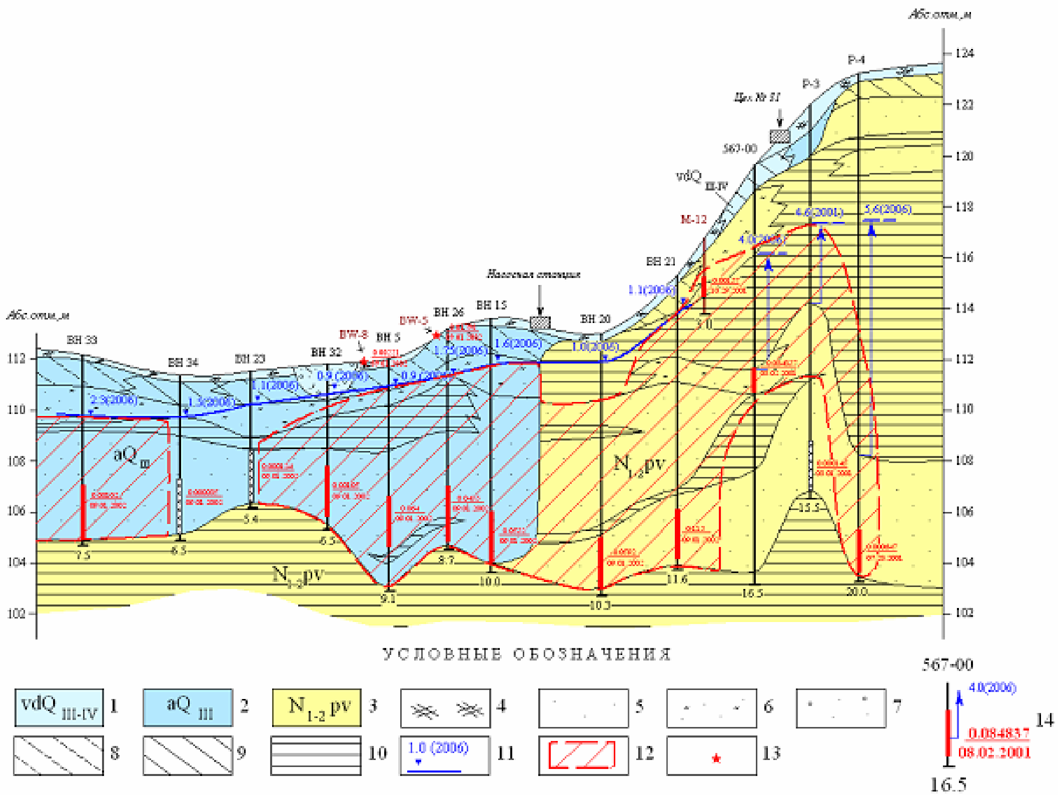

Fig. 13. Hydro-geological cross section on the line I-I

1 – Water permeable, but in fact waterless Upper-Quaternary and recent wind deposits; 2 – water-bearing horizon of Upper-Quaternary alluvial deposits; 3 – water-bearing complex of Lower-middle-Pliocene, Upper-Miocene deposits of Pavlodar series. Lithologic composition of rocks: 4 – soil-vegetable stratum; 5 – sand; 6 – clay sand; 7 – gravel sand; 8 – loam sand; 9 – loam; 10 – clay; 11 – table and depth of groundwater occurrence, m; in brackets – a year of observation. 12 – the area of groundwater mercury contamination. 13 – surface water sampling points. 14 – hydro-geological borehole. Numerals: on top – borehole number (name); at the bottom – borehole depth, m; on the right: in numerator – mercury concentration in water – mg/l; in denominator – sampling date. Hatched area – sampling interval. Red colored boreholes – the ones where mercury concentrations are more than MPC (0.0005 mg/l). By the arrow – occurrence depth of piezometric level, m; in brackets – a year of observation.

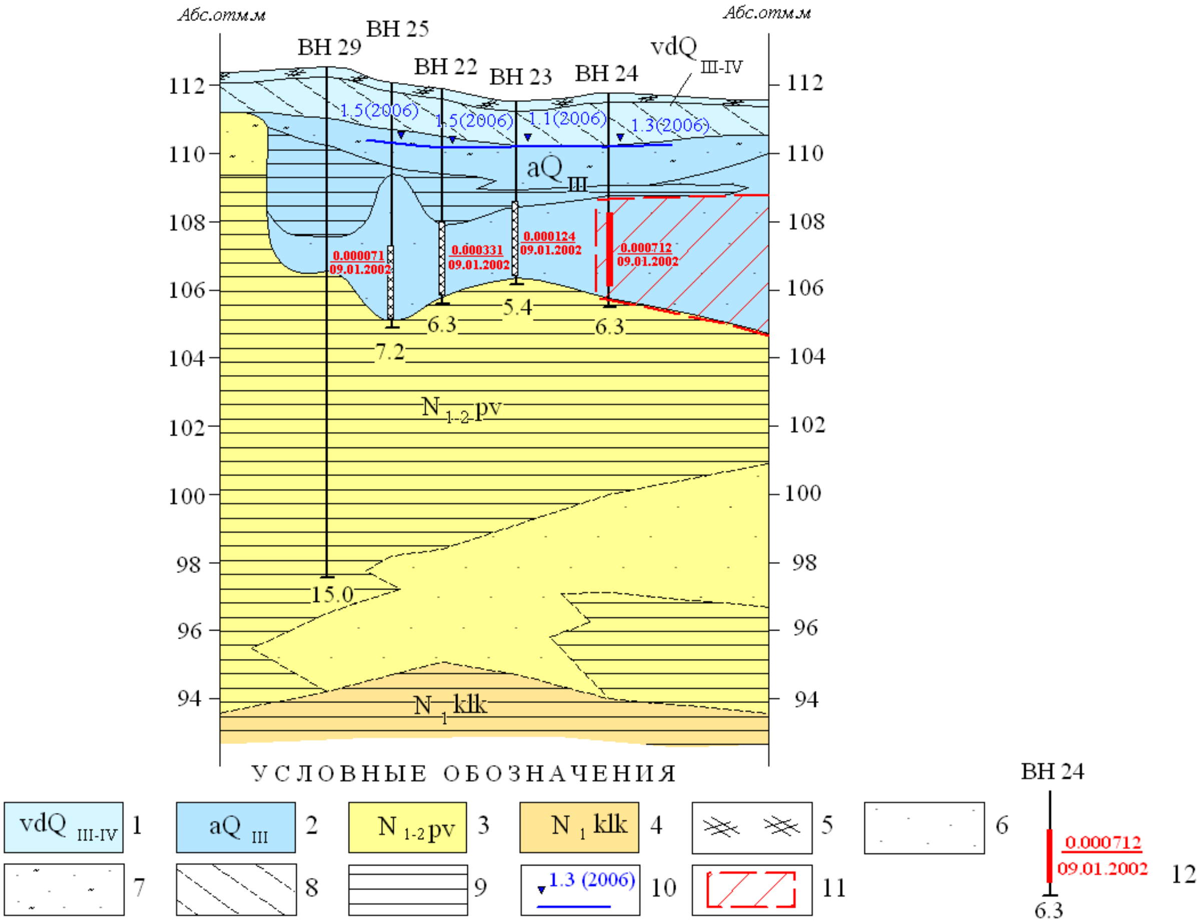

Fig. 14. Hydro-geological cross section on the line II-II

1 – Water permeable, but in fact waterless Upper-Quaternary and recent wind deposits; 2 – water-bearing horizon of Upper-Quaternary alluvial deposits; 3 – water-bearing complex of Lower-middle-Pliocene, Upper-Miocene deposits of Pavlodar series; 4 – waterproof rocks of Lower-middle-Miocene of Kalkaman series. Lithologic composition of rocks: 5 – soil-vegetable stratum; 6 – sand; 7 – clay sand; 8 – loamy sand; 9 – clay; 10 – table and depth of groundwater occurrence, m; in brackets – a year of observation; 11 – the area of groundwater mercury contamination. 12 – hydro-geological borehole. Numerals: on top – borehole number (name); at the bottom – borehole depth, m; on the right: in numerator – mercury concentration in water – mg/l; in denominator – sampling date. Hatched area – sampling interval. Red colored boreholes – the ones where mercury concentrations are more than MPC (0.0005 mg/l).

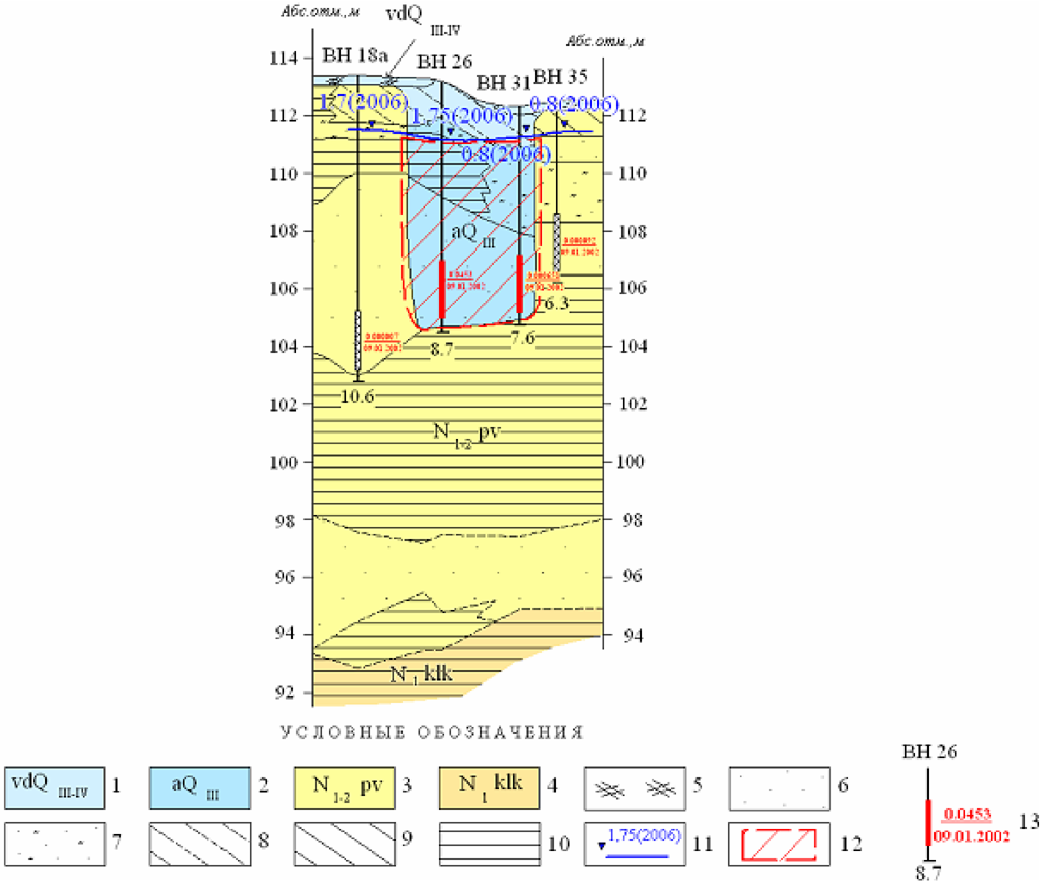

Fig.15. Hydro-geological cross section on the line III-III

1 – Water permeable, but in fact waterless Upper-Quaternary and recent wind deposits; 2 – water-bearing horizon of Upper-Quaternary alluvial deposits; 3 – water-bearing complex of Lower-middle-Pliocene, Upper-Miocene deposits of Pavlodar series; 4 – waterproof rocks of Lower-middle-Miocene of Kalkaman series. Lithologic composition of rocks: 5 – soil-vegetable stratum; 6 – sand; 7 – clay sand; 8 – loamy sand; 9 – loam; 10 – clay; 11 - table and depth of groundwater occurrence, m; in brackets – a year of observation; 12 – the area of groundwater mercury contamination. 13 – hydro-geological borehole. Numerals: on top – borehole number (name); at the bottom – borehole depth, m; on the right: in numerator – mercury concentration in water – mg/l; in denominator – sampling date. Hatched area – sampling interval. Red colored boreholes – the ones where mercury concentrations are more than MPC (0.0005 mg/l).

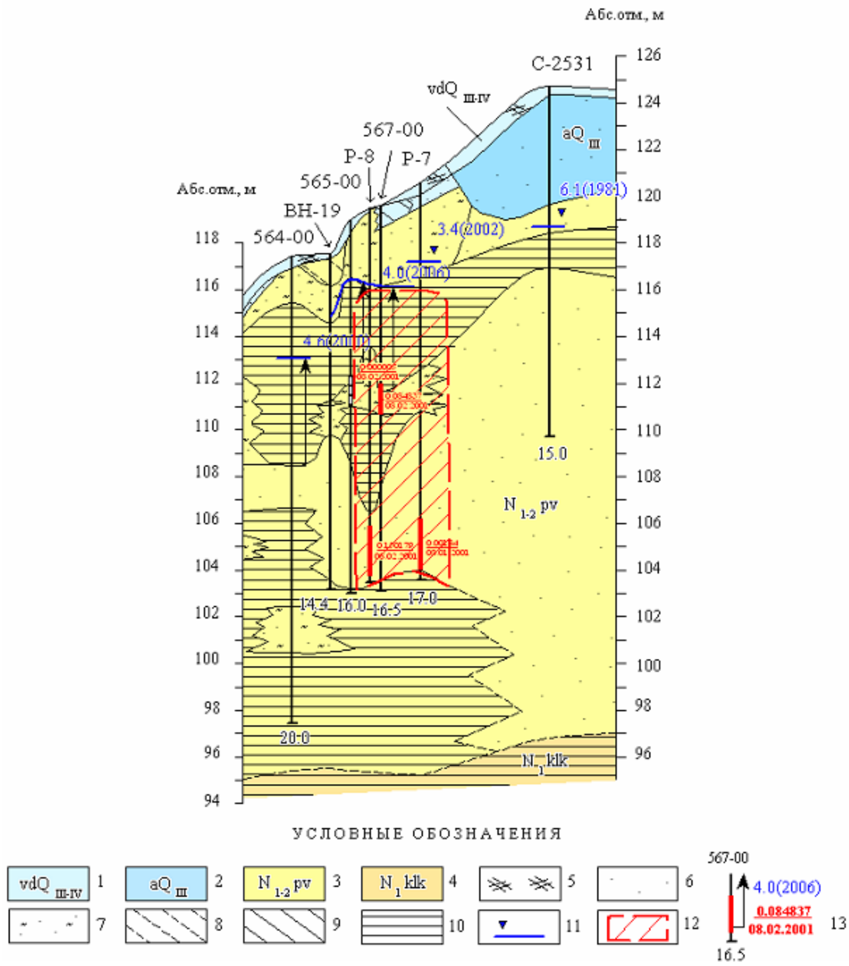

Fig. 16. Hydro-geological cross section on the line IV-IV

1 – Water permeable, but in fact waterless Upper-Quaternary and recent wind deposits; 2 – water-bearing horizon of Upper-Quaternary alluvial deposits; 3 – water-bearing complex of Lower-middle-Pliocene, Upper-Miocene deposits of Pavlodar series. 4 – waterproof rocks of Lower-middle-Miocene of Kalkaman series. Lithologic composition of rocks: 5 – soil-vegetable stratum; 6 – sand; 7 – clay sand; 8 – loam sand; 9 – loam; 10 – clay; 11 – groundwater table with free surface, m; 12 – the area of groundwater mercury contamination. 13 – hydro-geological borehole. Numerals: on top – borehole number (name); at the bottom – borehole depth, m; on the right: in numerator – mercury concentration in water – mg/l; in denominator – sampling date. Hatched area – sampling interval. Red colored boreholes – the ones where mercury concentrations are more than MPC (0.0005 mg/l). By the arrow – occurrence depth of piezometric level, m; in brackets – a year of observation.

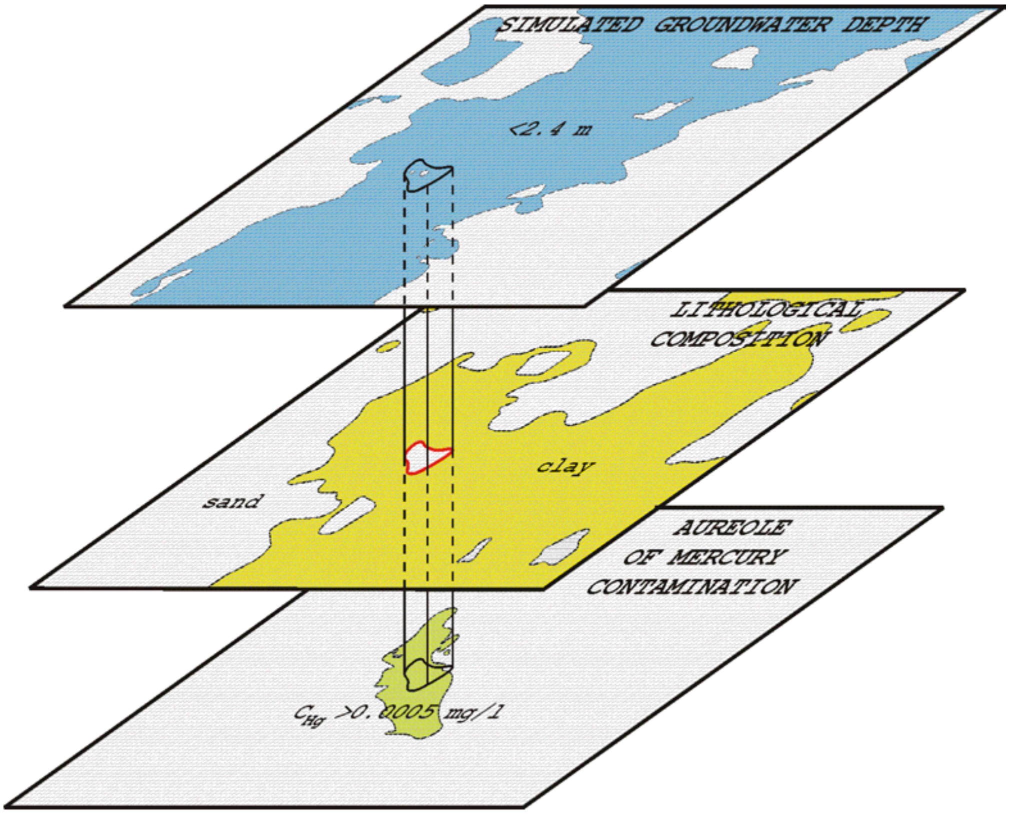

Fig.17. Zoning of the area of investigation according to groundwater occurrence depth, lithologic structure and mercury concentration in groundwater.

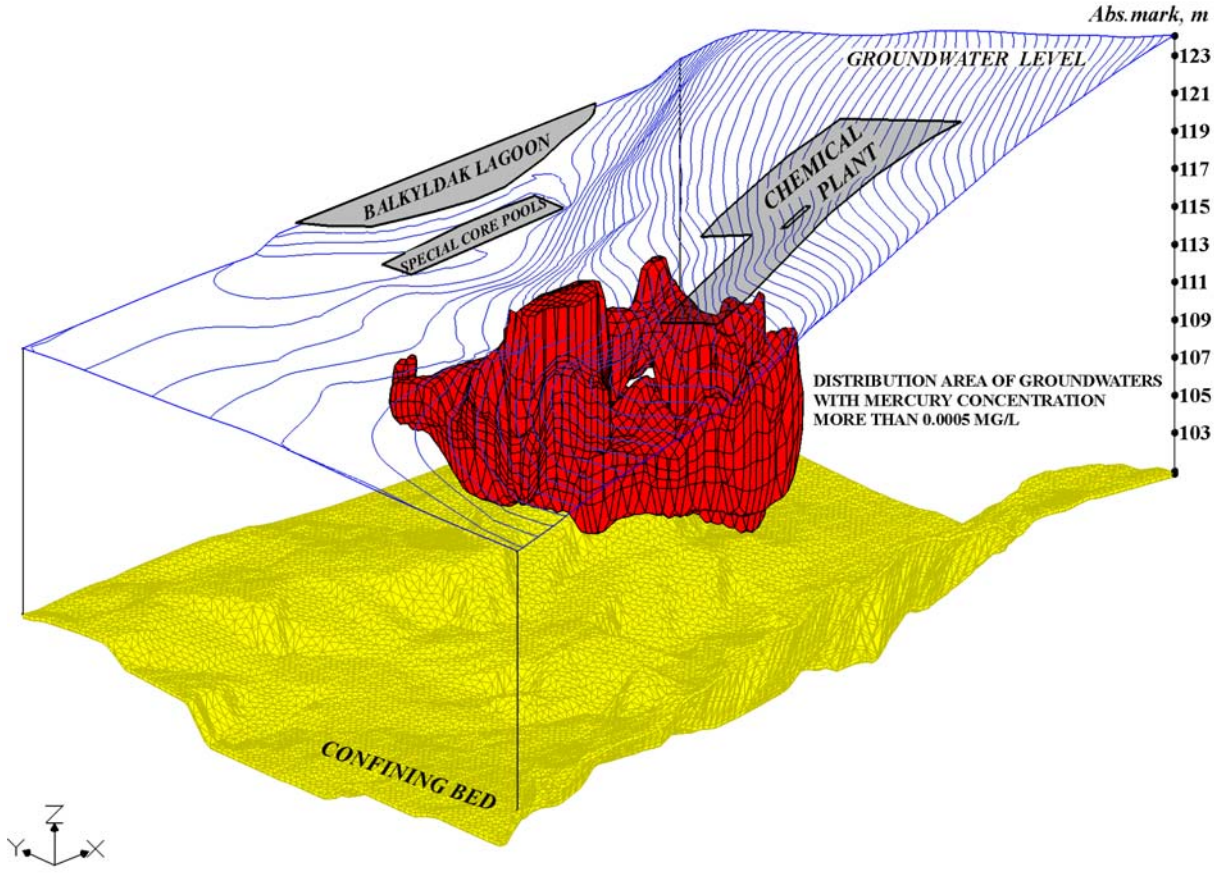

Fig. 18. 3D diagram of groundwater mercury contamination spread based on the results of modeling of 2006.

ANNEX 3: Abstracts of papers published for the second year

1. S.M.Ullrich, M.A.Ilyushchenko, I.M.Kamberov, T.W.Tanton. Mercury contamination in the vicinity of a derelict chlor-alkali plant. Part I: Sediment and water contamination of Lake Balkyldak and the River Irtysh. The Science of the Total Environment, V. 381, 2007, P. 1-16

2. S.M.Ullrich, M.A.Ilyushchenko, T.W.Tanton, G.A.Uskov. Mercury contamination in the vicinity of a derelict chlor-alkali plant. Part II: Contamination of the aquatic and terrestrial food chain and potential risks to the local population. The Science of the Total Environment, V. 381, 2007, P. 290-306

The threat of polluting river Irtysh by mercury was caused by high losses of Hg during 1975-1993 at chlor-alkali production in Pavlodar outskirt in Kazakhstan. These losses were the highest among similar factories in the former USSR. In average they could be estimated as 1.6 kg Hg per ton of produced caustic soda (total losses could be estimated as 1310 tons of those 1100 tons were non-counted mechanical losses of metal mercury). The majority of this mercury was concentrated beneath electrolysis factory and formed the hotspot of groundwater contaminated by soluble mercuric chloride. The other adverse effects that took place include: losses of Hg-contaminated wastewater from plant drain; contamination of topsoil; and contamination of surface water in wastewater storage – lake Balkyldak (having capacity more than 80 million m^3). The closest sites subject to risk of mercury pollution are village Pavlodarskoye (having 200 ha of groundwater fields) and river Irtysh located in 3-5 km to the west from chlor-alkali production.

Original design of clean-up was developed in 1995. The scope of designed works included excavation and treatment of heavily contaminated materials with the purpose to recover marketable metallic mercury. Conducted research allowed revision of strategy for the management of mercury contamination in Pavlodar. Instead of expensive and non-effective recovery of Hg from wastes with high level the containment strategy was proposed assuming isolation of major hotspots from atmosphere, surface run-off and groundwater. In 2003-2005 the hydraulic barrier (cut-off wall) was constructed around four major hotspots. The depth of cut-off wall reached basalt clay at 15-20 m and its width was 0.6 m. The total length of the barrier is 3588 m. Contaminated topsoil was excavated to the depth 0.5 m and removed to the sites isolated by cut-off walls. The hotspots were covered by clay on total area of 180000 m^2. All buildings were demolished and the debris were placed into the cell (3 m deep trench) lined with 0.5-m clay layer. These materials were further stabilized with cement and covered with asphalt layer. Therefore the monolith storage facility with total area 15671 m^2 was constructed which is stable against the impact of groundwater and surface run-off.

Starting from 2005 local authorities initiated 15-year Program of mercury contamination monitoring in Northern industrial area of Pavlodar. This Program is expected to answer the question whether the clean-up activities implemented to date are sufficient. US EPA gives a support to this program via ISTC having launched three-year project K-1240 from 2006.

3. M.A.Ilyushchenko, L.V. Yakovleva (editors). Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, 99 p.

4. M.A.Ilyushchenko. Problems of demercurization of industrial objects within the former USSR Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 15.

5. A.D. Akhmetov, V.A.Bednenko. Experience of demercurization works within the territory of former PO "Khimprom", Pavlodar. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 18.

6. V.Yu. Panichkin. Risk assessment from groundwater mercury pollution of the Northern area of Pavlodar industrial region by the methods of mathematical modeling. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 20.

7. O.L. Miroshnichenko. Methods and technology of creation of the system of mathematical models with different scales for groundwater mercury pollution within the industrial area of Pavlodar city. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 21.

8. M.A. Ilyushchenko, R.I. Kamberov, L.V. Yakovleva. Post-demercurization monitoring and risk assessment in the Northern industrial area of Pavlodar city. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 23.

9. S.A. Abdrashitova, W. Davis-Hoover, R. Devereux. Development of technology of bioremediation of mercury contaminated groundwater for Pavlodar outskirt. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 24.

10. V. Ye. Khrapunov, B. L. Levintov, S. A. Trebukhov. Development of integrated demercurization technology and facilities for its implementation in Kazakhstan. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 25.

11. F.I. Ingel, J. Eyless, P. Eckl, M. Chiba, S.N. Khussainova. Risk assessment of human health under exposure with low-level of mercury. Proceedings of International Workshop "Environmental mercury pollution: mercury emissions, remediation and health effects" (Astana, Kazakhstan, May 28 – June 1, 2007). Program, Abstracts. Astana, 2007, P. 42.

All these publications have been put on the website http://Hg-Kazakhstan.narod.ru

ANNEX 4: Information on patents and property rights.

Annex to quarterly technical report
on execution of the ISTC project K-1240p
for the period 1.07.06-30.09.06

ACTIVITIES ON IDENTIFICATION, PROTECTION AND EXPLOITATION OF INTELLECTUAL PROPERTY CREATED UNDER THE PROJECT

E V E N T S	Yes	No
Non Disclosure Agreement (NDA) has been signed (with collaborator or with other persons or organizations)		**No**
New solution (below called "innovation solution") that could be considered as an object of Intellectual Property has been identified (created, obtained)		**No**
Notification on identification of innovation solution has been submitted to the ISTC		**No**
Formal description of innovation solution has been submitted to the ISTC		**No**
Solution to protect innovation in a form of commercial secret has been taken		**No**
Application for registration of software / Data Base / IC Topography has been submitted		**No**
Application for patent has been filed		**No**
National		**No**
Eurasian		**No**
PCT		**No**
Application for patent in the territory of other country has been filed		**No**
Patent has been obtained		**No**
National		**No**
Eurasian		**No**
other countries		**No**
Registration of software / Data Base / IC Topography has been confirmed		**No**
Formal request for licensing / technology transfer has been received		**No**
Negotiation on licensing / technology transfer has been formally initiated		**No**
Agreement on licensing / technology transfer has been signed		**No**
Agreement on licensing / technology transfer has been registered		**No**
Request for patenting financial support has been submitted to the ISTC		**No**
Request for patenting consulting support has been submitted to the ISTC		**No**

Project manager M.Ilyushchenko