In early 1993, Chevron and the Republic of Kazakhstan formed a joint venture company, Tengizchevroil, to develop petroleum resources along the northeast margin of the Caspian Sea. This venture produced an immediate need for detailed images, base maps, and topographic maps of the joint venture block.

Aerial Photo Survey Kicks Off Joint Chevron/Kazakhstan Tengiz Oil Project

Tight deadlines normally don't phase Pat Caldwell, remote sensing analyst at Chevron Overseas Petroleum Inc. But when a request came in May 1993 for a photo survey by year-end of the Tengiz oil field in the former Soviet republic of Kazakhstan, he almost said 'no'.

"My first thought was that it wasn't possible," Caldwell recalled, "because I knew we'd need to have the aerial photography completed by August, which gave us less than two months to plan it. Ordinarily that wouldn't be a problem, but this wasn't ordinary. We'd never managed a project in the Commonwealth of Independent States and no Westerners had ever been allowed to acquire and take aerial photographs out of Russia."

Chevron and Kazakhstan are partners in Tengizchevroil, a joint venture company whose ultimate goal is to increase oil production in the Tengiz J.V. block along the northeast margin of the Caspian Sea.

The venture group needed accurate baseline maps, topographic maps, and images for engineering and environmental purposes. An aerial photo survey was seen as a key, initial step to realizing the overall goal.

With help from Tobin Surveys Inc. in San Antonio, Texas, Tengizchevroil completed a successful photo survey of the 80 x 50-kilometer block. In the process, Tengizchevroil became the first Western group to acquire and take aerial products out of the CIS.

GETTING STARTED

"There were no accurate, detailed maps so no one knew exactly where the wells were," said Caldwell, who functioned as the aerial survey project manager for Chevron.

Initially, Caldwell and his associates combined satellite imagery, computer aided drafting (CAD) and single receiver hand-held GPS technologies to help evaluate the area and generate regional maps. The satellite images, dated 1986 to 1993, were acquired by Landsat, SPOT and Russian KFA-1000 cameras. Although the images provided a regional understanding of terrain, vegetation patterns, land-use, the Caspian coastal zone, and oil field infrastructure, they lacked sufficient detail to document field conditions. The next step was an accurate aerial survey.

AERIAL SURVEY

Finding a qualified aerial survey company that could obtain clearance to fly in CIS airspace wasn't easy. Caldwell couldn't locate a Russian company that had ever run a private aerial photo survey or any European firms that had flown in Russia.

"The red tape involved to bring in someone from the outside who had never flown in Russia would have been unrealistic given our deadline," he said. "We had to find someone in Russia with the mapping expertise to understand what we wanted and who could obtain a plane, crew and equipment."

Tobin International Inc., a subsidiary of Tobin Surveys, Inc., a full-service photogrammetric engineering and mapmaking company, met those requirements. It recently had formed a joint venture with a Russian agency, State Center Priroda. And although Tobin crews hadn't actually flown in Russia, with the Priroda affiliation they could obtain permission. That process and the accompanying permits, visas and contract negotiations took two months.

"First we had to get permission to fly in the airspace over the Tengiz field, then we had to get permission to take the film out of the country," said Don Stone, president of Tobin.

Stone's colleagues at Priroda, the Russian equivalent of the U.S.G.S., secured a Russian Turboprop An-30 aircraft, and crew experienced in aerial photography from a Ukrainian company. The plane had two vertical camera mounts down the middle and two oblique camera mounts on the side. Priroda loaned a Zeiss Jena LMK-1000 aerial camera. Tobin staff operated the portable Garmin 100 AVD GPS navigation system.

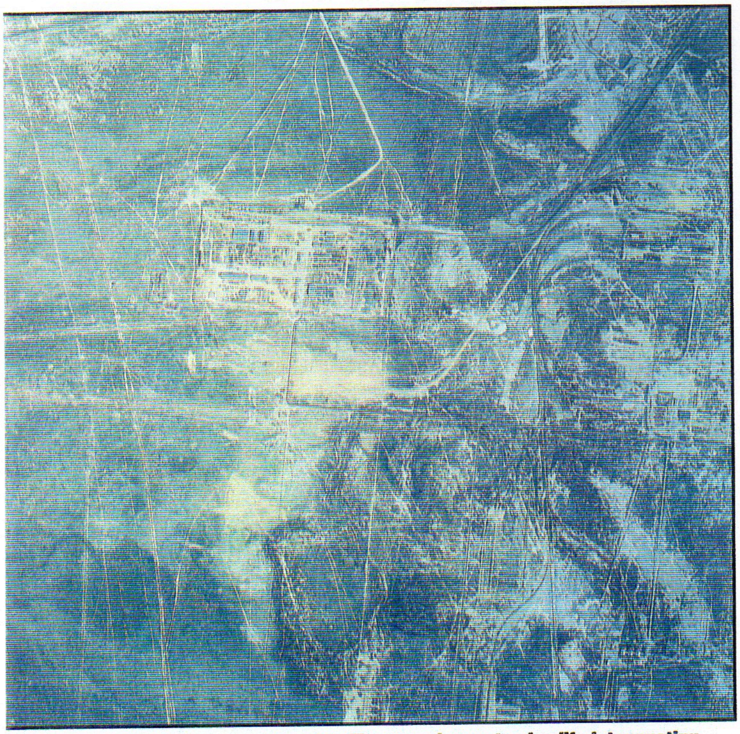
The Tengiz J.V. Block has little relief and is characterized by intensely developed oil fields and vast expanses of undeveloped terrain covered with reworked eolian deposits (sand dunes and ponds).

COLOR AND COLOR IR FILM

Caldwell specified Kodak Aerocolor Negative Film 2445 to simplify interpreting location and environmental conditions, and Kodak Aerochrome Infrared Film 2443 to maximize resolution and provide vegetation, soil moisture content and chemical analysis.

"I specified both types of color film because I needed a full spectral range for environmental studies — identifying plant communities, changes in the water table and chemical analysis," Caldwell explained. "Only Kodak offered the film combination that allowed me to match color and color IR. If I scan a Kodak color image and adjust the color bands correctly, and scan the same image shot in color IR, I end up with four separate distinct bands of data, rather than three, because the sensitivity of the two films don't overlap much.

"Four bands of color gives me a much broader spectrum of data," he continued. "For example, salinity is picked up by both color and IR bands, so when we put them together we can answer discriminating questions about changes in the water table."



Kodak Aerographic color film was chosen to simplify interpreting location and environmental conditions by workers in the field while color infrared was specified to maximize resolution and provide information on vegetation and moisture content of the soil.

The Priroda camera crew also shot Russian 7 1/2-inch B&W film, which they developed in Russia and sent to the Kazakh government. The black and white camera became the control because the photographer was able process a few frames each night to check the exposures.

During the survey planning stages, Caldwell took hardcopy plots and digital files (on a Macintosh Powerbook laptop computer) of the regional maps and georeferenced satellite images to Moscow for planning sessions with officials from Priroda and Tobin International.

SURVEY SCALE AND FLIGHT PLAN

Caldwell chose a survey scale of 1:20,000 as a compromise to satisfy environmental and engineering needs. "With today's film and digital technology, we can interpret 1:20,000 enlarged photographs as if they were 1:5,000 photography," he said.

Tobin developed a flight plan with 18 north-south flight lines consisting of about 50 frames each. Given tight flying windows, the plan was to fly the color first because color is easier to understand and interpret. Then the team would fly the color IR. Caldwell was less concerned with completing IR images of the middle of the block, because it was industrial with little water or vegetation, the two elements that color IR discerns well.

SENSITOMETRIC TESTS

Prior to taking the film out of the CIS, Stone contacted Precision Photo Laboratories, Inc. in Dayton, Ohio, to run sensitometric data on both film types. Lab technicians exposed a 21 step sensitometric wedge on each piece of film to verify sensitometry and film characteristics. The purpose was to define a baseline to determine if the film changed due to temperature, humidity or x-ray because Chevron didn't know what kind of ambient conditions the film would be subjected to.

GROUND CONTROL NETWORK

Before the photo survey began, Chevron staff established a ground control network using GPS and other surveying methods to create a geodetic matrix for the aerial photography. Tobin/Priroda determined the flight line placement and developed a 3 x 9 km grid of 187 preferred photo points. Because of time constraints, Caldwell marked about 71 points so they would be visible on the 1:20,000 air photos.

Gary Simmang from Tobin operated the GPS equipment in the plane to make sure the pilot was flying correct flight lines. Because of the plane configuration, he mounted the GPS antenna through a bubble window in the top of the plane near the rear. He relayed information to the navigator via a headset and interpreter. If any part of the flight line was bad, the entire line was reflown because the client wanted each flight line to be continuous on a roll. In the end, the maximum deviation from a flight line was 250 meters.

COMPLETING THE AERIAL SURVEY

The J.V. block wasn't easy to fly because the terrain was flat and featureless. "There's only about a seven or eight meter difference between the lowest and highest points," said Simmang, "but the pilot and navigator were very skilled and we only had problems on two lines that were 90 percent over water. We had to fly those visual."

The weather conditions were similar to those in the Gulf of Mexico. "When the sun gets high enough to warm the ground, cumulus clouds start popping up," explained Stone. "We needed days when the wind from the east, which was drier, would come and blow the cloud cover off. We photographed when the sun was at least 35 degrees above the horizon."

To maintain the film in stable ambient conditions, It was stored in ice chests. On the return journey to the United States for processing, Caldwell checked the coolers as excess baggage, rather than sending them as air freight.

PROCESSING AND PRINTING AERIAL IMAGES

"Printing the color was a problem because the topography was featureless and indistinguishable," explained Bob Rolfe of Precision Photo. "There were no normal reference points — just a hint of green foliage — and we hadn't seen the terrain. So we made sample prints at different color balances for the client to approve. Each color balance reflects different features of the terrain.

Caldwell took a set of workprints back to Kazakhstan for initial field work. With the workprints in hand, he was able to recommend how the images should be color balanced. With that information, Tobin and Precision Photo worked on a mosaic of the block, in color IR and natural color, which was the prelude to photo interpretation.

"When we first printed the color IR, our instructions were to match the color of the color IR transparency film," Rolfe explained. "But when we went back to reprint, we showed the client that we could modify the color balance and the contrast of the reproduction and help them differentiate between subtle tones that couldn't really be seen in the original.

"We had the original record on the film and the argument was made that the most accurate record of the scene is what is on the film," he continued. "But the information on the film is linear and one of the reasons for the aerial survey was to do photo interpretation and identify items on the ground. Sometimes by distorting that from what the film saw you are able to do a better job in interpretation."

Pat Caldwell, remote sensing analyst for Chevron Overseas Petroleum, Inc., interprets a stereo pair of aerial photographs taken of the Tengiz oil field in Kazakhstan.

"I'll go back into the block and field check critical areas," said Caldwell. "An air survey that is not field checked is not worth as much as one that is."

With the initial photography completed, Caldwell can breathe a little easier and begin to disseminate the wealth of information captured. "Normally you do a project like this as part of a comprehensive mapping package, but we had to take a short view — completing the aerial survey first."

Establishing base maps, documenting existing environmental conditions for archival purposes and extensive photo interpretation of the area will be among the first uses of the aerial survey.

"This project will be a prototype for future Chevron work in the CIS," Caldwell concluded.

EOM

AN AERIAL PHOTOGRAPHY SURVEY USING RUSSIAN AND WESTERN TECHNOLOGY, TENGIZ J.V. BLOCK, KAZAKHSTAN*

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[4] Chevron Petroleum Technology Co., Houston, Texas

ABSTRACT

In early 1993 Chevron and the Republic of Kazakhstan formed a joint venture company, Tengizchevroil, to develop petroleum resources in the 4000 km^2 Tengiz Joint Venture Block located along the NE margin of the Caspian Sea. The creation of Tengizchevroil produced an immediate need for detailed images and basemaps of the J.V. Block in order to meet project management requirements of facility engineers, environmental engineers, and earth scientists. Tengizchevroil contracted the Russian agency State Center Priroda and Tobin International, Inc. as they had just negotiated a joint venture agreement to integrate Russian and Western aerial photography technology. Color photography was chosen to simplify interpreting location and environmental conditions by workers in the field while color-infrared photography was specified to maximize resolution and provide information on vegetation and moisture content of the soil. The scale of the survey was 1:20,000 using a Russian aircraft (An-30), Ukrainian flight crew, Zeiss-Jena LMK-1000 aerial camera, Kodak film, and the portable Garmin 100 AVD GPS navigation system. Tobin developed a flight plan with 18 flight lines consisting of 50 frames each. The turboprop Russian aircraft, which was flown out of Astrakhan, Russia, proved to be a very stable platform with ample space onboard for the flight crew, camera crew, and quality control personnel. The location and condition of roads, levees, powerlines, pipelines, landfills, and facilities could be determined from the air photos.

1.0 BACKGROUND

In early 1993 Chevron and the Republic of Kazakhstan formed a joint venture company, Tengizchevroil, to develop petroleum resources along the NE margin of the Caspian Sea (Figure 1). The onshore area has little relief and is characterized by intensely developed oil fields and vast expanses of undeveloped terrain covered with reworked eolian beach deposits (sand dunes, tidal flats and ponds). The creation of Tengizchevroil produced an immediate need for new large-scale basemaps of the joint venture block in order to meet project management requirements of facility engineers, environmental engineers, and earth scientists. These mapping requirements could only be met if Tengizchevroil acquired new aerial photographs.

Previous to the agreement, Chevron had successfully applied satellite remote sensing, computer-aided drafting (CAD), and single receiver hand-held GPS technologies to help evaluate the area and generate regional maps (Goodwin and Ellis, 1994). These satellite images and maps provided a superb base upon which to plan the air photo survey. In order to understand what Tengizchevroil needed from the aerial phototgraphs, we designed a 1-page questionnaire for distribution to management and operational groups (Figure 2). Based on the responses and many interviews, we determined that both color and color-infrared photography at a nominal scale of 1:20,000 was needed. Color photography was chosen to simplify interpreting location and environmental conditions by the workers in the field, while color-infrared photography was specified to maximize resolution and provide information on vegetation and moisture content of the soil and oil at the surface.

*Presented at the 10th Thematic Conference on Geologic Remote Sensing, San Antonio, Texas , 9-12 May 1994

2.0 DESIGNING THE AERIAL PHOTOGRAPHY SURVEY

A strategic decision was made to utilize Russian aerial photography resources to acquire the data. CAD maps and georeferenced satellite images were taken as hardcopy plots and digital files (on Macintosh Powerbooks) to Moscow in mid-May 1993 for planning sessions with the Russian agency State Center Priroda and Tobin International, Inc. Priroda and Tobin had just negotiated a joint-venture agreement to integrate Russian and Western aerial photography technology. Priroda, Tobin and Chevron worked out an agreement (the first of its kind in the former Soviet Union) and divided project responsibilities.

Priroda was responsible for the airplane, photogrammetric camera, photographers and the permits. Tobin planned the acquisition program, delivered the unexposed film to Kazakhstan, and set QC procedures for the whole project. The acquisition program consisted of 18 flight lines, each with 50 frames. Based on photogrammetric requirements, a map was developed that specified where ground control points (GCP's) should be established. Chevron and Tengizchevroil were responsible for marking these GCP's in the field, documenting terrain conditions to assist with color balancing the prints, and interpreting the photographs.

3.0 ESTABLISHING GROUND CONTROL POINTS FOR PHOTOGRAMMETRY

SPOT and Landsat TM images were used to help plan a highly accurate, cm-level, geodetic control network across the oil fields. This network was established by July 1993 in order to provide horizontal and vertical control by Chevron's Navigation and Tengizchevroil's Kazakh survey groups. The surveyors used geodetic quality, single frequency GPS receivers in differential mode. Many of the GCP's in the geodetic network also fulfilled photogrammetric/topographic requirements (provided x,y, and elevation control to photogrammetric tie points). Surveyors preceded the paneling crew by more than a month and utilized, where possible, existing Russian survey monuments that are marked with steel "tripods" (Figure 3A). The surveyors emplaced steel monument posts in concrete within the oil field (Figure 3B).

A field crew of 2 Uzbekistan laborers, a Russian interpreter and P.D. Caldwell laid out over 70 panels at both geodetic network GCP's and other photogrammetric tie points across the JV Block (Figure 3). The sites used 2 strips of paneling material, each 15 m long, arranged in the shape of an "L". The white, fiberglass-reinforced plastic sheeting material was held in place with rebar rods and stakes (Figure 3B). Panels withstood 65 km/hr winds that carried loose sand and also nibbling by camels. The paneled GCP's were located in the field using a hand-held GPS receiver and a georeferenced 1:50,000 panchromatic SPOT image. The crew reached paneling sites in the middle of the JV Block in a Russian 4wd Niva. Points along the southern and eastern edges of the block were accessed using a Russian MII-8 helicopter (Figure 4A).

4.0 ACQUIRING THE AERIAL PHOTOGRAPHS

Flight operations commenced on August 4th, less than 10 weeks after the May meeting in Moscow. The photographs were acquired using a Russian aircraft (An-30) with a Ukrainian flight crew (Figure 5A), a Zeiss-Jena LMK-1000 aerial camera operated by the Priroda photographer Valeri Ageev (Figure 5B), and Kodak color and color IR aerial mapping films. To ensure compatibility with western standards, Tobin sent 2 representatives to the field. One monitored the operation and the other utilized a portable Garmin 100 AVD GPS navigation system to continuously check the aircraft's position and direct the flight lines.

For logistical reasons, the operation was based in Astrakhan, Russia, some 500 km west of Tengiz. The aerial photographs were acquired along north-south flight lines at 10,000 feet altitude. The photography window was usually limited to less than 3 hours per day as cumulus cloud build-up characterized most afternoons. Acquisition was delayed many days because of poor weather conditions. After 12 days in the field, the acquisition phase of integrated Russian and Western aerial photography program accomplished its primary objectives and was terminated. Mosaicking the aerial photographs into indexes was facilitated by using the CAD map created from georeferenced SPOT panchromatic images.

5.0 UTILIZING THE AERIAL PHOTOGRAPHS FOR MAPPING

Acquiring, processing, and printing the aerial photographs in this remote and previously inaccessible setting cost about 30 to 40 times more than comparable work with our highest resolution satellite images. However, the approximate 0.5 to 0.7 m resolution of the aerial photographs was far greater than the satellite images that were previously used for mapping and interpretation of terrain, facilities, and infrastructure (Figure 6). With these new aerial photographs (approximately 900 color and 600 color IR) we were able to build upon our previous interpretation of satellite images and provide detailed and up-to-date maps of terrain and man-made features for engineering, environmental, earth science, and management groups.

Ongoing and planned facilities and infrastructure construction within the oil fields is a significant capital expenditure. The primary administrative and residential area for expatriates in Tengiz, the "Hungarian Camp", is shown as an example of the suitability of these aerial photographs for engineering work (Figure 6). The 1989 SPOT panchromatic image (Figure 6A) provided the basis for a good preliminary map. However, the 1:20,000 true color aerial photographs (Figure 6B) are able to provide the base for detailed maps at scales of 1:5,000 and larger. Orthorectification of these aerial photographs should provide basemaps with an x,y,z accuracy of ± 2 m.

Developing an accurate roadmap was a high priority for supporting field operations. Prior to the aerial photograph survey, a CAD map had been interpreted from the black and white (B&W) SPOT images that attempted to delineate a road network across the oil fields. This map proved to be inaccurate because we were unable to differentiate between unpaved roads (gravel, rock, or graded-dirt), dirt trails, seismic line scars, and pipeline scars. Although on the aerial photographs roads and road types were easier to interpret, a vehicle needed to be seen on a road or trail in order to distinquish between active and abandoned roads and trails. Mapping the types of dirt roads (including their probable use, i.e. impassable soft sand tracks, light vehicle, and heavy vehicle) required studying the photographs and driving the roads.

Documenting features across the J.V. Block was a major objective with the aerial photographs. Initially an area along an estuary was identified using our SPOT panchromatic image as a probable village (Figure 7A). Examination of the color aerial photograph indicated that this settlement was abandoned and may potentially be an archeological site (Figure 7B). Color infrared photography was obtained to assist in developing an environmental baseline. Even in mid-summer, after 2 months of >32°C weather in this desert environment, color IR film captured unique vegetation signatures (Figure 8) that enabled interpretation of small agricultural sites and shallow groundwater areas. In other parts of the area, color IR film helped locate oil at the surface from seeps and spills.

Stereoscopic viewing of the aerial photographs revealed subtle topographic relief across the flat terrain and greatly assisted in interpreting waste pits, landfills, elevated road and railroad beds, elevated pipelines, levees used for ponding, etc. The stereoscopic interpretations of geomorphic and man-made features will be transferred into a CAD workstation that displays orthorectified color aerial photographs with selected vector files superimposed (oil wells, ground water monitoring wells, existing seismic lines, road network, etc.). This digital mapping process will ensure high levels of accuracy are continually maintained during the interpretation.

Field work was needed to validate the interpretation of the aerial photographs. In addition, field work upgraded the map by documenting the condition of many interpreted features, such as 6 oil wells that were plugged and abandoned, refuse pits that were abandoned, free-flowing water wells, the exact location of some seismic grid intersections, and a rail spur that was unfinished. Combined with field information, the aerial photographs are providing a detailed and accurate record of terrain and man-made features across the remote Tengiz Block of Western Kazakhstan.

6.0 ACKNOWLEDGEMENTS

We thank Tengizchevroil and Chevron Overseas Petroleum Inc. for supporting the aerial photograph survey and this publication. Emily Davies and Mike Manka of Tengizchevroil's Safety and Environmental Affairs Group were essential for our success. State Center Priroda provided timely support and the professional Ukrainian flight crew, led by Captain Valery M. Laguta, ensured acquisition success. Tobin's field representatives Lowell Haack and Gary Simmang ensured that every aspect of the photo mission met Tobin's rigid photogrammetric specifications. Don Stone of Tobin and Jim Ellis and Mike Quinn of Chevron Overseas Petroleum Inc. provided continuous support from the home office. Bob Rolfe, Precision Photo Laboratories, Inc. of Dayton Ohio, did an excellent job managing the Kazakh titling, color-balancing and printing of the film.

7.0 REFERENCES

Goodwin, P. B. and J. M. Ellis, 1994, "Using Remote Sensing Technology to Develop an Environmental and Engineering Baseline, Tengiz J.V. Block, Kazakhstan." In *Proceedings of the Tenth Thematic Conference on Geologic Remote Sensing*, San Antonio, 9-12 May 1994, 12 p.

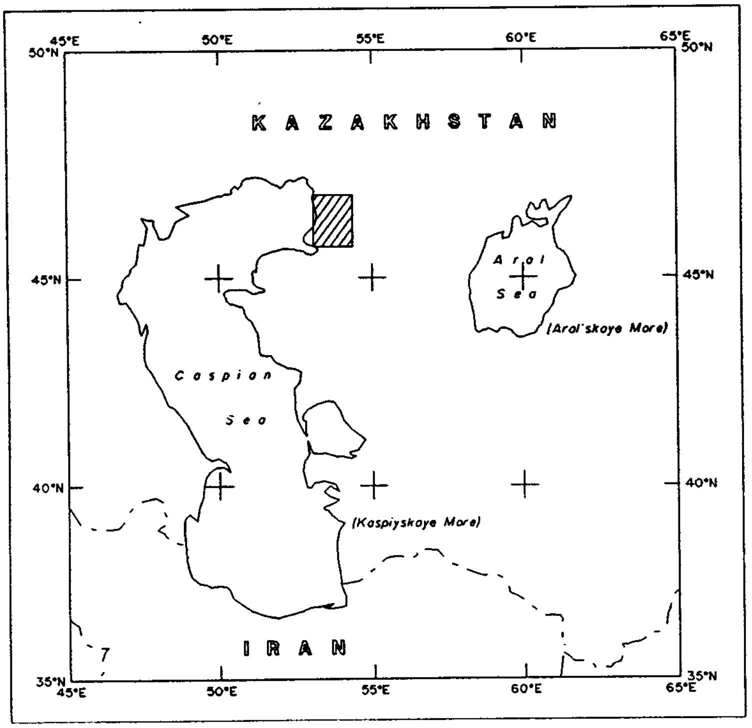


Figure 1. Location map showing Tengiz along NE coast of Caspian Sea

Air Photo Survey User's Questionnaire

Chevron will soon have an aerial photo survey flown of the Tengizchevroil joint venture block. Planning for the survey is now underway. An opportunity exist to incorporate into the project specifications for more than just a basic photo reconnaisnce. From the perspective of your work speciality please answer the following questions.

Return (ASAP) the questionaire to the address on the back
or
FAX it to Pat Caldwell 510-842-3030

What **size** object needs to be differentiated? (4"?)

What **kind** of object or surficial condition needs to be differentiated?

What spatial (cartographic) accuracy is needed? [±10meters?]

Do you need a topographic map generated from these photos? (Y/N) What level of accuracy and what contour interval(±2meters and 1 meter?)

Is color important or is the sharper, more informative infra-red color O.K., or are both needed?

How many copies of specific areas might you need?

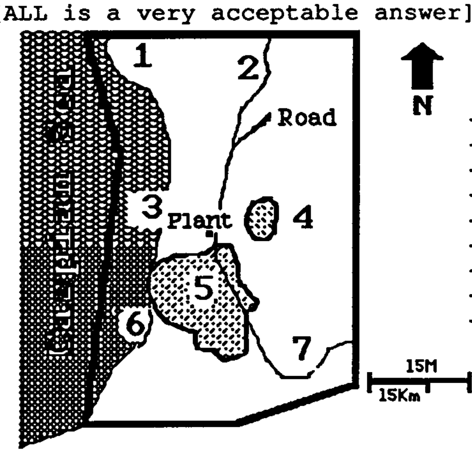
Do you need cartographic reference on each photo? [Lat/Long or X/Y]

Do you need a cartographic overlay information on each photo or only on the mosaics?

In what grid system(s) do you need or prefer the survey be controlled? [Lat/Long, northing/easting, local Kazak grid, other]

In what language(s) should the annotations on the photos be?

Using the sketch below indicate what areas are of most importance to your work? [ALL is a very acceptable answer]



__ **All**
__ **1) Teren Uzek**
__ **2) Karaton**
__ **3) W. Korolev**
__ **4) Korolev**
__ **5) Tengiz**
__ **6) Ogai**
__ **7) Sarakamys**
__ **other area(s)**
____
____
____

Do you need to see the same level of detail across the entire JV block or higher in the Tengiz/Korolev area and less elsewhere?

____________________ / ______________ / ________________
Name / Position / Phone or FAX

Figure 2. Aerial photograph survey user's questionnaire

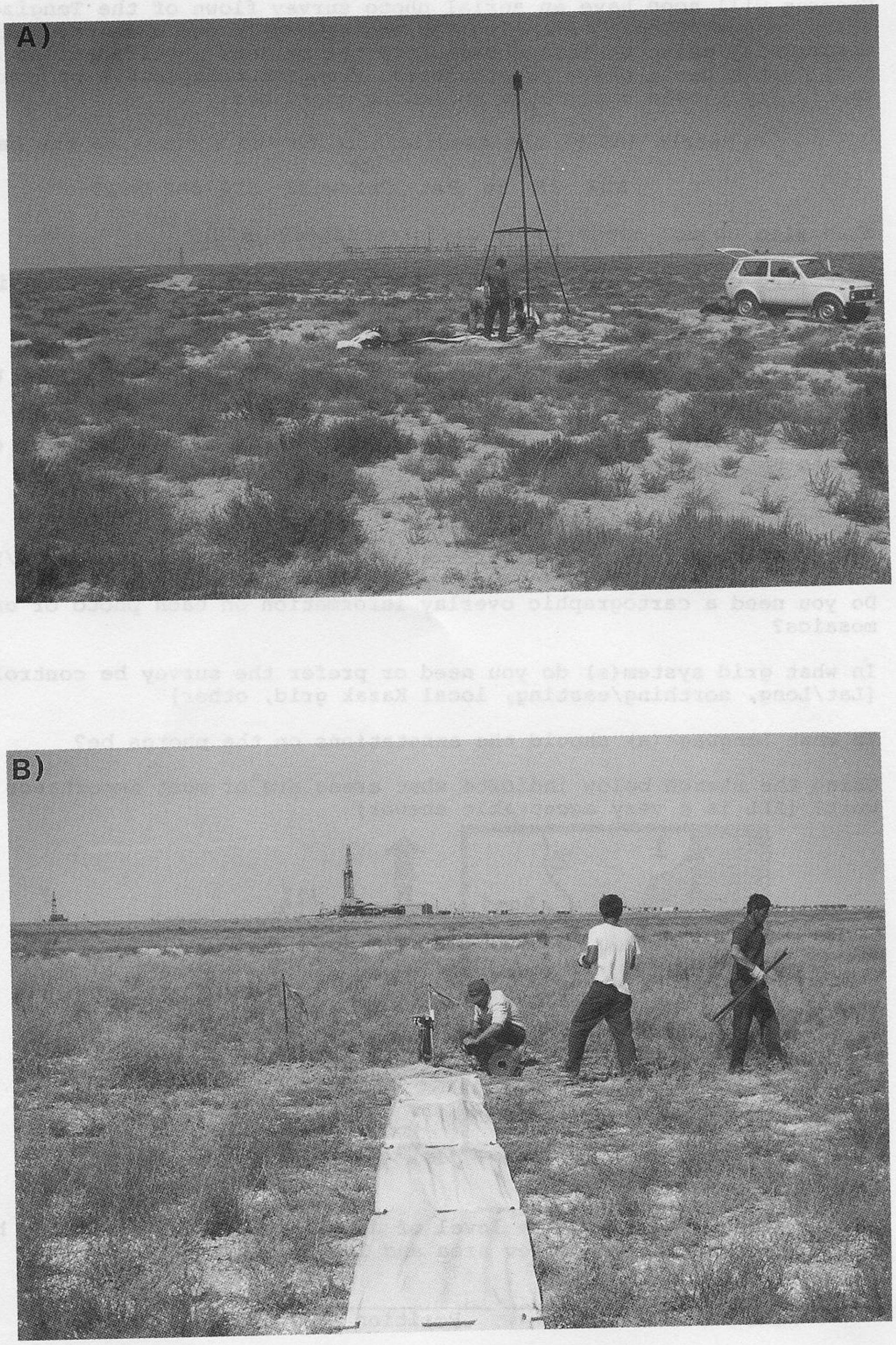


Figure 3. A) Typical survey point where existing Russian control markers (tripod) were resurveyed with GPS. Note flatness of terrain. B) Close-up of white, reinforced plastic sheeting used for paneling. Paneling held in place with rebar rods and stakes. Steel monument post in concrete installed by surveyors.

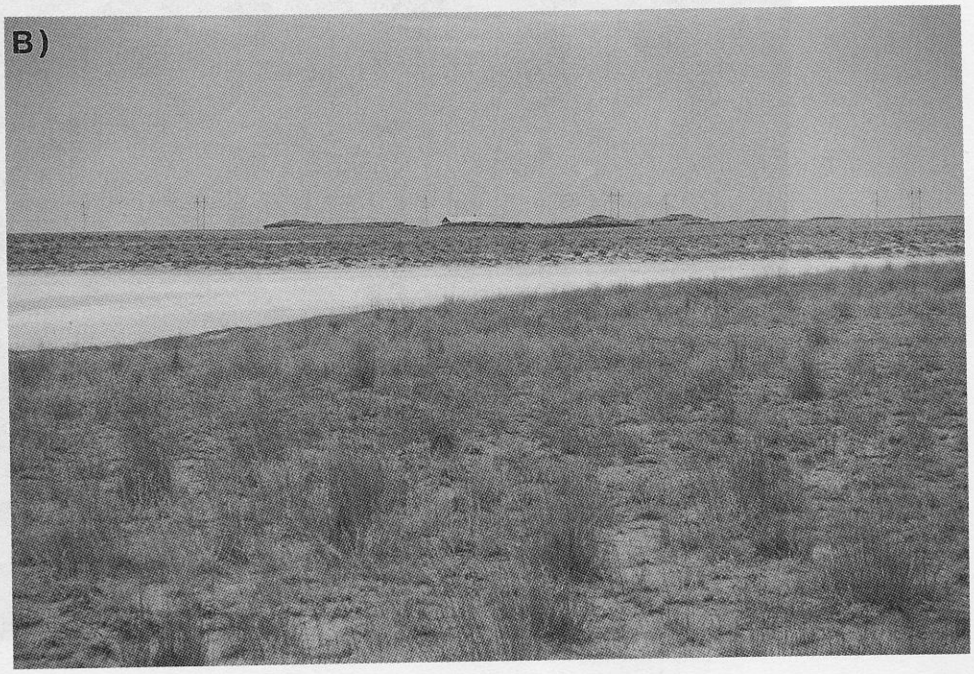
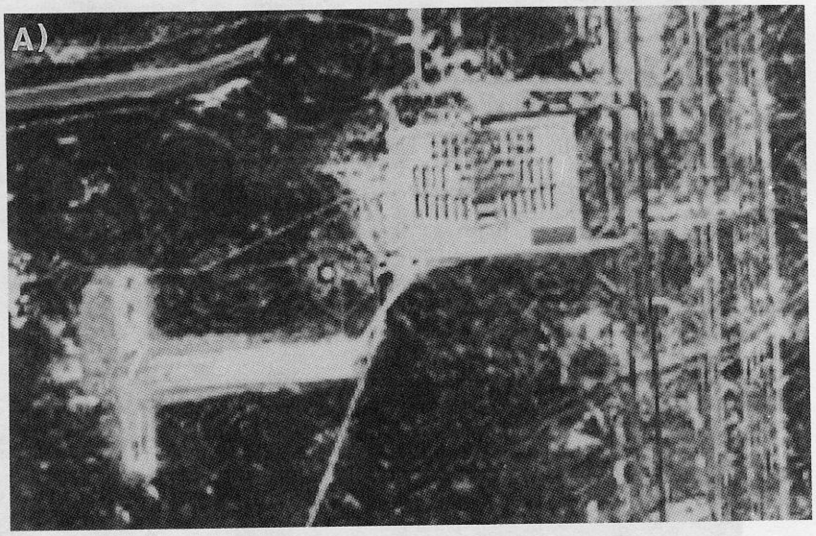


Figure 4. A) A Russian Mil-8 helicopter used to reach more distant portions of Tengiz Block. Flight crew enjoying air temperature of 40°C. B) View looking NE toward a winter cattle station (see Figure 8). Low-lying white area in center has an alkali crust.

Figure 5. A) Russian An-30 photo reconnaissance aircraft. B) Spacious interior of An-30 with LMK-1000 Zeiss-Jena camera in foreground.



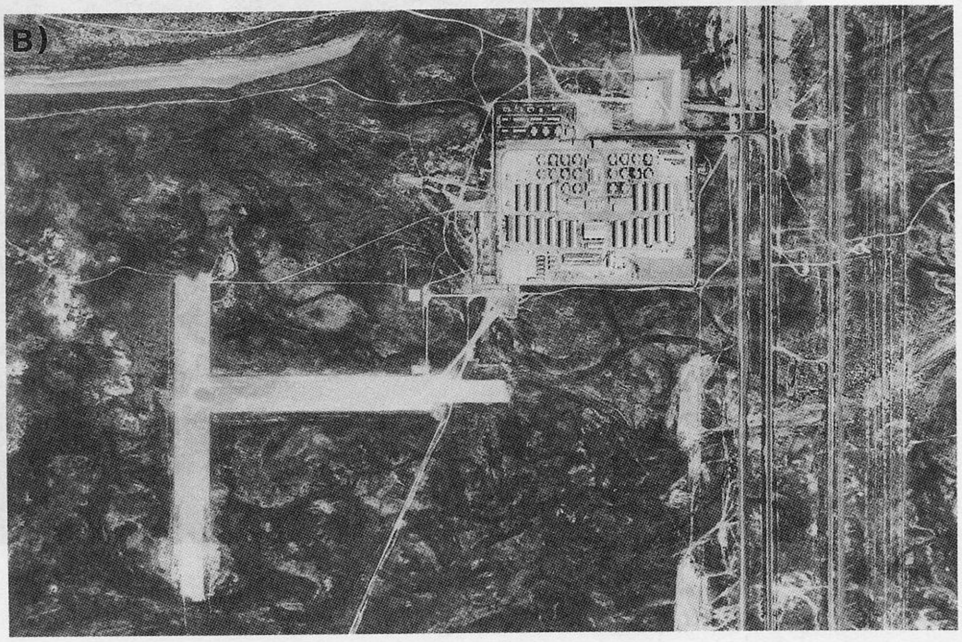


Figure 6. (A) SPOT panchromatic image and (B) B&W rendition of color aerial photograph of facility in Tengiz, airstrip, primary/secondary roads, and railroad. Aerial photograph can support detailed engineering and planning functions. SPOT @ 1989 CNES

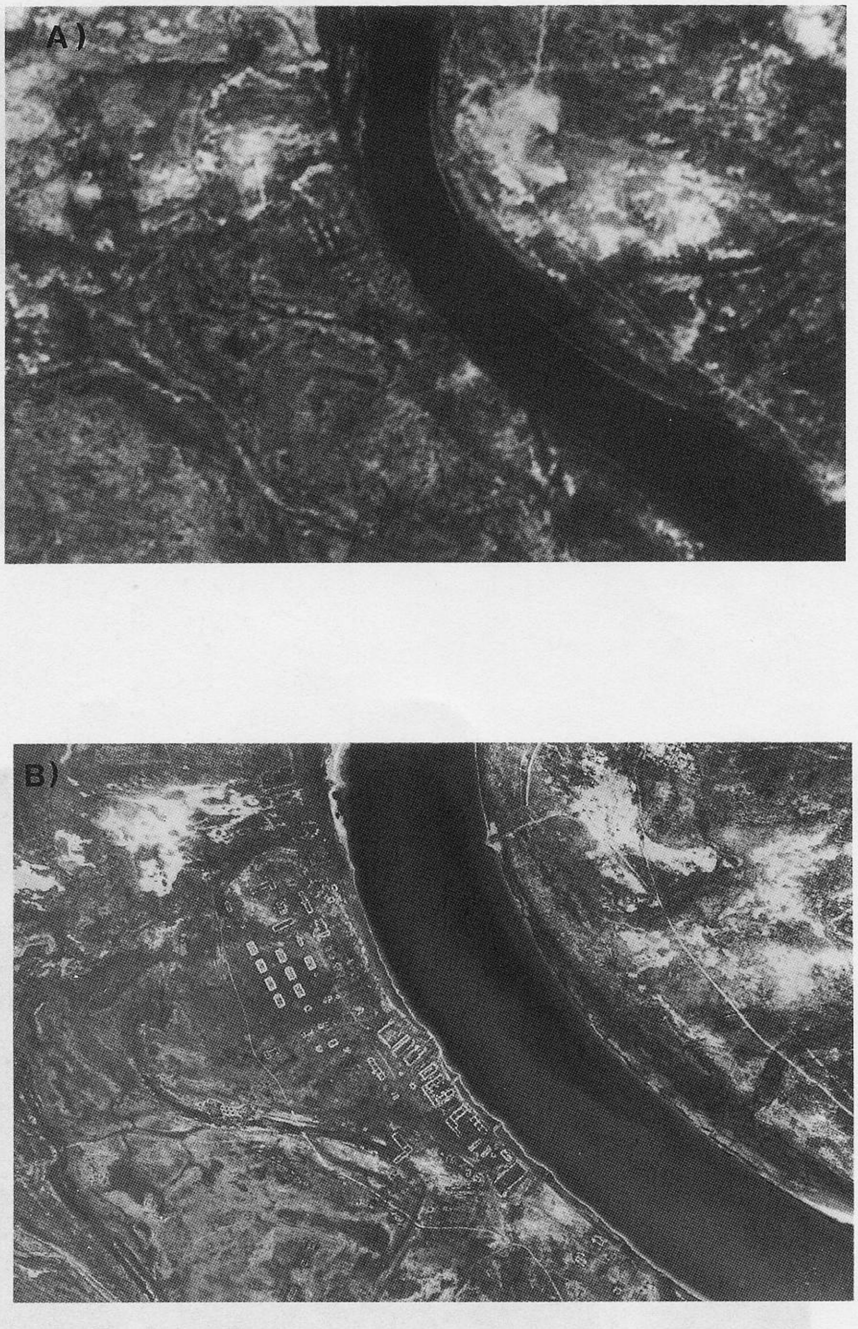


Figure 7. (A) SPOT panchromatic image and (B) B&W rendition of color aerial photograph of area along an estuary. On SPOT the area was identified as probable village, however, on aerial photograph area interpreted as abandoned village, perhaps an archeological site. (SPOT @ 1989 CNES)

Figure 8. B&W rendition of color infra-red photograph used for environmental baseline studies. Dark feature at arrow is winter cattle station (bright red on color IR photograph; see Figure 4B for ground view).