3 Overview of Phase I-a

3.1 Approach to the investigations in Phase I

Also, an assessment of (a) the amount of data that can or should be acquired, i.e., the data requirements for each of the investigations and the investigations to be performed in terms of the type, detail and scope are related to (b) the quality and accuracy of the results needed for analysis and modeling. For this reason, a cyclical approach to the investigations, data analyses and evaluations were established, (Figure 3.1). This approach to assessment of data requirements and investigations has been done repetitively during this Phase.

The approach to the surface-based investigations and techniques applied in Phase I was as follows:

- Obtain data on the geological environment from surface utilizing a multi-disciplinary approach,
- Construct models of the geological environment,
- Predict the effects of shaft excavation on the geological environment.

The applicability of the techniques employed can be evaluated by a comparison of the predictions and the actual observations made during shaft excavation in Phase II.

3.2 Phase I-a and I-b (7)

The most important aspect of Phase I is to develop the expertise and techniques required to investigate, analyze and evaluate the geological environment to 1,000 m depth. Phase I was divided into Phases a and b to facilitate data analysis and the iterative approach to model development. Conceptual models of the geological environment were constructed in Phase I-a (1996-1999) from the data generated prior to and during the period of this report. Thereafter, the cycle of investigation, analysis and evaluation would be repeated in the 2nd half of Phase I (Phase I-b, starting 2000 FY) to examine the above-mentioned correlation between data requirements and investigations and the quality and accuracy of the investigation results.

In Phase I-a data obtained from the multi-disciplinary surface-based investigations were used to develop the geological, hydrogeological, hydrochemical and rock mechanics conceptual models (Figure 3.2).

The Phase I-b investigation plans are based on the results of the investigations in Phase I-a and in consideration of various research restrictions such as schedule and budget. Phase I-a models are to be revised according to the results of the analyses and evaluations made during the Phase I-b. The repetition of the cycle shown in Figure 3.1 enables us to understand how the models are improved by the revision and the correlation between quantity and quality of the data and the investigations.

Furthermore, by assessing and validating the revised models in subsequent Phases, it is expected that the usefulness of the surface-based investigations and associated analyses and evaluations can be assessed. Consequently, it may be possible to determine data requirements and the variety and scope of investigations for model construction.

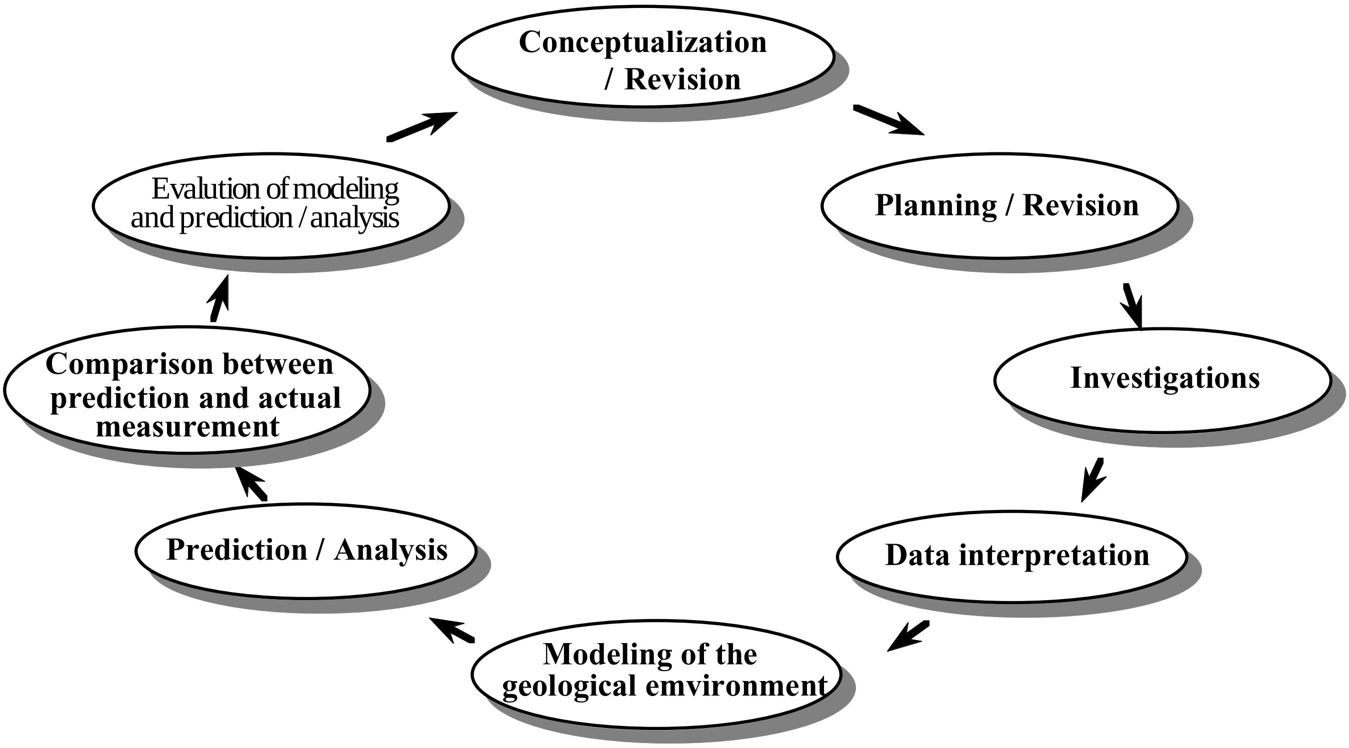

Figure 3.1 Approach to investigations, analysis and modeling

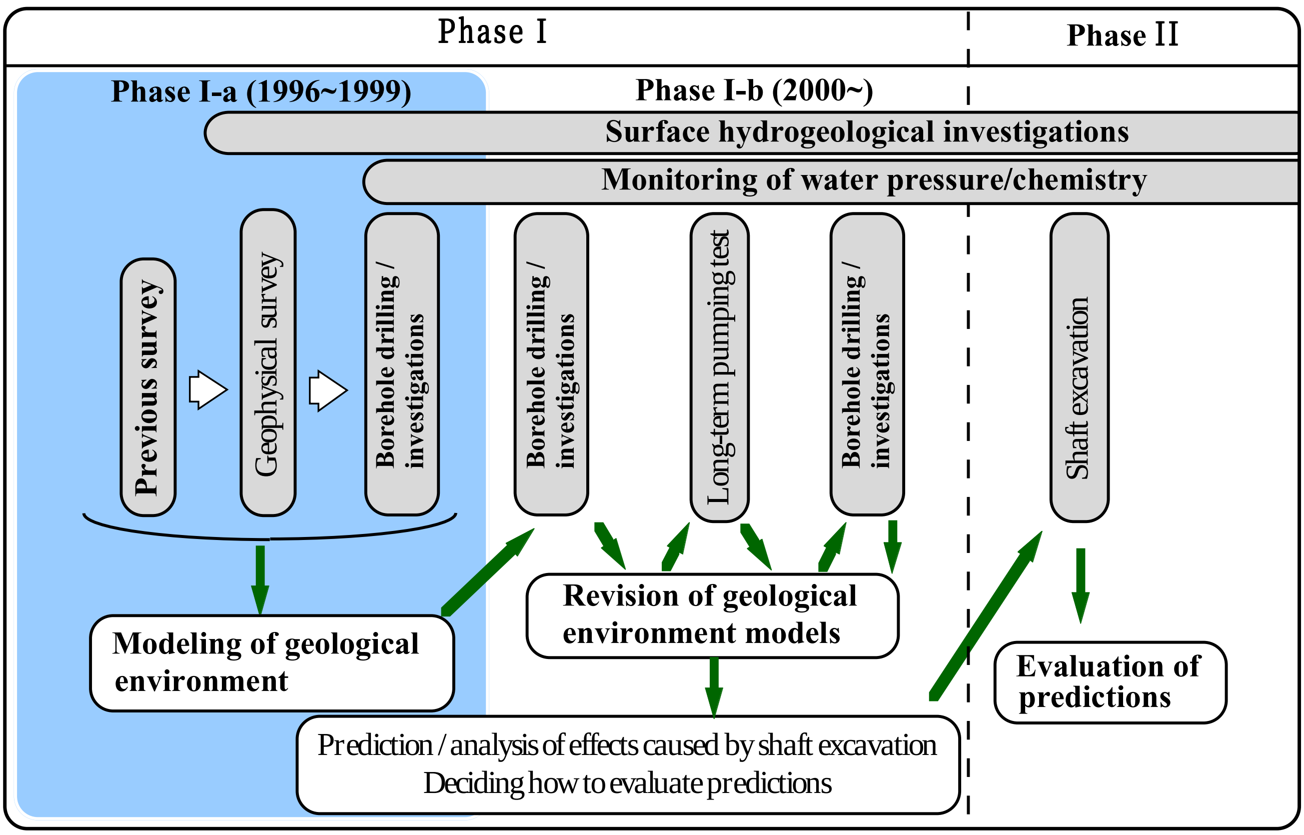

Figure 3.2 Research plan of the Phase I of the MIU Project

3.3 Overview of the investigations carried out in Phase I-a

Major investigations performed in Phase I-a include geophysical surveying, i.e., electro-magnetic and reflection seismic surveys, hydrological investigations and drilling of three 1000 m deep boreholes, MIU-1, 2 and 3. Investigations also included detailed core logging, structural analysis, BTV surveying, geophysical logging, hydraulic testing and in situ stress measurements (hydraulic fracturing tests) in the boreholes. Chemical and mineralogical analyses, determination of rock mechanical properties of the rock mass and of in situ stress by acoustic emission (AE) and deformation rate analysis (DRA) tests was done using core samples. Long-term monitoring of pore water pressure was carried out in boreholes drilled before the MIU Project commenced. Tables 3.1 and 3.2 and Figure 3.3 show the activities and purpose of the investigations, the outline of the borehole investigations and the location where investigations were carried out, respectively.

In order to understand and illustrate the geological environment underlying the Shobasama Site, four models were constructed; geological, hydrogeological, hydrochemical and rock mechanics conceptual models. Construction of each model was done iteratively, in two Stages. In the first stage, only data obtained from literature surveys and the results of earlier geoscientific research, excluding data from the MIU Project, were used. Following model construction, the models were revised using new data from the MIU Project.

・**Geology**

Models were constructed for two areas: the Shobasama Site and an area encompassing the Shobasama Site of about 4 km × about 6 km (Figure 3.4). The latter area was established for groundwater flow simulations.

For each area, two models were constructed. The first model was constructed using data obtained from literature surveys and the earlier geoscientific research, which excludes MIU Project results. The second model was constructed with the data from Phase I-a added to the data used for the first model.

・**Hydrogeology**

Two models were constructed for the above-mentioned more regional area encompassing the Shobasama Site (about 4 km × about 6 km) with the purpose of improving the accuracy of groundwater flow simulations.

The first model was constructed using data obtained from literature surveys and the earlier geoscientific research, which excludes MIU Project results. The second one was constructed adding data from the Shobasama Site to the data used for the first model. Groundwater flow simulations were also carried out.

・**Hydrochemistry**

Using data obtained from literature surveys and the earlier geoscientific research, a hydrochemical model was constructed. Groundwater sampling and analyses were planned to be carried out in and after 2000 FY.

Using those data, the hydrochemical model would be improved.

・**Rock mechanics**

The conceptual model was constructed only for the Shobasama Site. It was done in distinct stages as understanding was developed from successive boreholes at the Shobasama Site. First, the data obtained from geoscientific research and from MIU-1 were used. Next, the model was revised by adding data from MIU-2 and finally the model was revised with data from MIU-3.

In the final Phase I-a model, the rock mass has been divided into zones according to physical/mechanical properties and in situ stress.

・**Investigation techniques and equipment**

The MIU Project plays a role as a site for the application and testing of investigation techniques and equipment developed by TGC. TGC applies existing and developmental investigation techniques and equipment to actual investigations and to the extent possible adapts and improves them.

Additionally, literature surveys of overseas research experience are carried out to examine the evaluation techniques and methods used; for example, for the prediction of effects caused by shaft and drift excavations.

Furthermore, the basic concepts utilized in designing of facilities are examined to develop the engineering technologies needed for the deep underground.

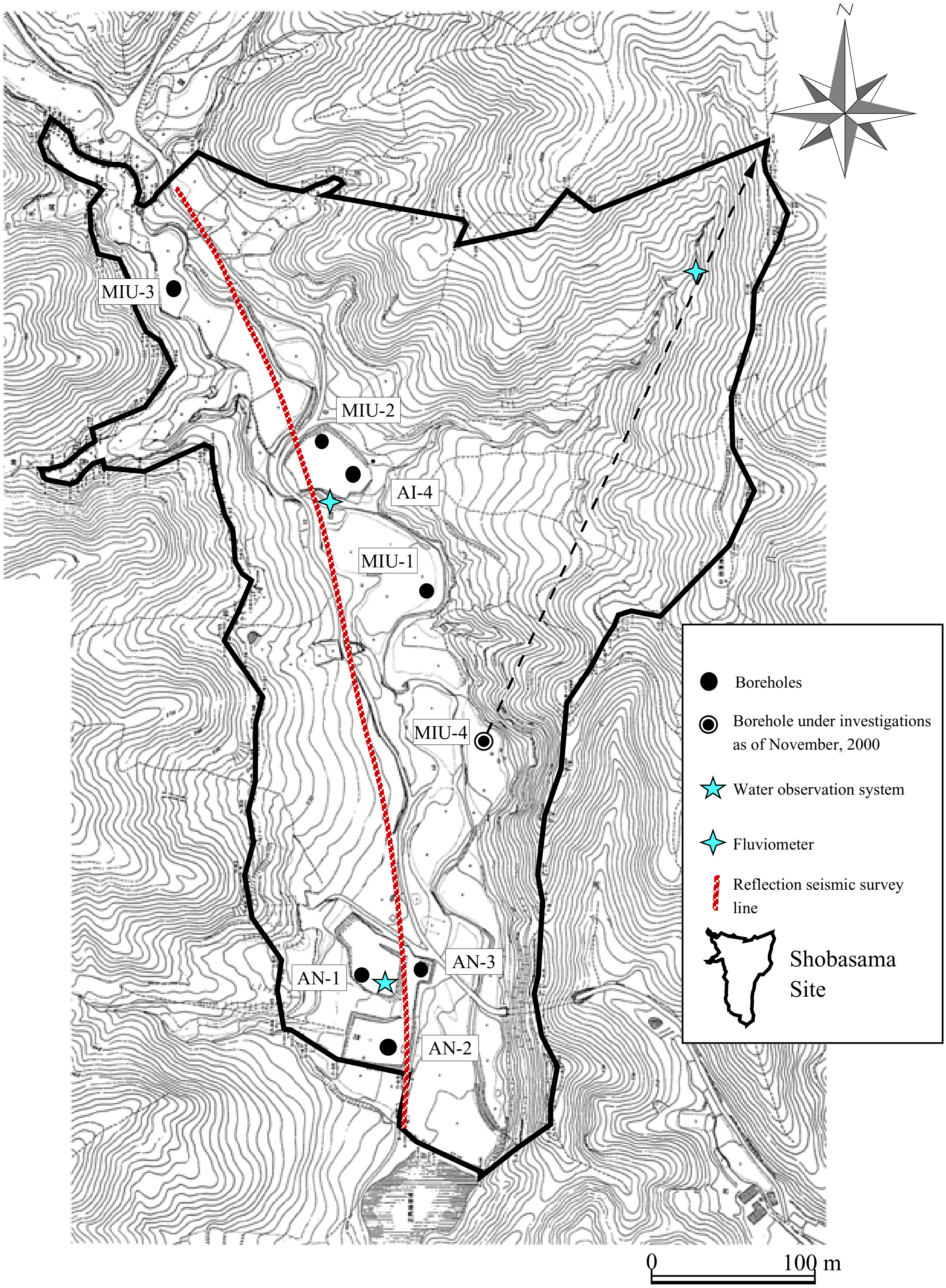

Figure 3.3 Location map of boreholes in the Shobasama Site

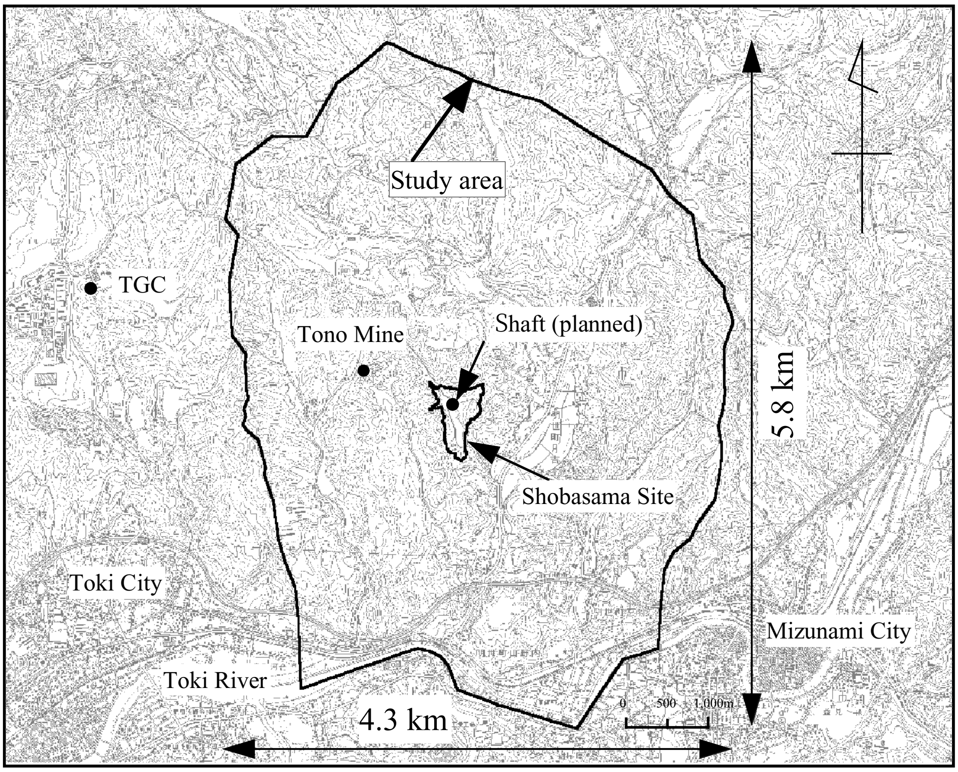

Figure 3.4 Location map of study area and Shobasama Site

Table 3.1 Details of investigations in Phase I-a
(1996 FY to 1999 FY)

Discipline/ Activity	Method	Purpose
Surface hydrological investigations	・**Meteorological observations** ・**Water level observations** ・**Soil moisture observations**, etc.	Estimate groundwater recharge rate
Water level monitoring	・**Seepage observations** (AN-1, AN-3)	Obtain data on steady state (static) groundwater levels and its response to borehole drilling.
	・**MP observations** (AN-1)	Obtain in situ data on steady state pore water pressures and changes caused by borehole drilling.
Geophysical surveying	・**Electric survey** (Resistivity method, 1 survey line, 200 m) ・**Electromagnetic survey** (Magnetotelluric, MT) ・**Reflection seismic survey** (1 survey line, 600 m)	Estimate distribution and continuity of unconformity, geological structure, alteration zone and fracture zone, etc.
Borehole investigations Existing boreholes ・AN-1(about 1,000 m) ・AN-3(about 400 m) New boreholes ・MIU-1,2 and 3 (about 1,000 m) Geology Hydrogeology Hydrochemistry Rock mechanics	・**Geological survey** Detailed core logging, structural analysis, optical microscopy, Geophysical surveying, BTV investigations, etc.	Confirm geology and geological structures, (fractures, faults and dykes) which act as groundwater flow paths.
	・**Hydraulic testing - hydrogeology** Permeability tests (pulse/slug) (in 3 holes×about 30 intervals) Pumping test (3 holes × 10 intervals)	Obtain in-situ data of hydraulic conductivity of groundwater flowpaths and changes in hydraulic conductivity with depth.
	・**Geochemical Analysis** Rock (core) sample analysis (3 holes)	Understand geochemistry of geological formations and changes in geochemical properties with depth.
	・**Rock mechanical tests** Physical/Mechanical tests (3 holes × 10 locations) In situ stress measurement (3 holes × 10 locations)	Understand physical/mechanical properties of granite and changes with depth.

Table 3.2 Details of borehole investigations in MIU-1, 2 and 3 boreholes

		MIU-1	MIU－2	MIU-3
Depth (m)		1011.8	1012.0	1014.0
Diameter		HQ（about 100 mm）	HQ（about 100 mm）	HQ（about 100 mm）
Drilling fluid		Fresh water	Fresh water	Fresh water
Geophysical logging*		○	○	○
BTV investigations		○	○	○
Pumping tests (100 m intervals (no. of intervals)		10	10	11
Single borehole hydraulic tests, 6.5m intervals (no. of intervals)		30	30	23
Flowmeter logging		○	○	○
Mineralogical test**		○	○	○
Age dating（using rock core: Fission track method）		○	×	×
Physical/ mechanical property test (no.of tests)	Apparent density	180	20	40
	Effective porosity	180	20	40
	Water content	180	20	40
	Seismic wave velocity	180	20	40
	Uniaxial compression test	90	20	10
	Brazilian test	30	40	10
	Triaxial compression test	90	10	10
In situ stress measurement (number of measurements)	AE/DRA	10	20	10
	Hydraulic fracturing	-	10	10

*: Electrical, Micro resistivity, Density, Neutron, Gamma ray, Acoustic, Temperature, Caliper and borehole deviation

** : Modal/chemical composition analysis