6.3 Earthquake Resistant Plan for Facilities Structure and Equipment

This section is related to Damage estimations described earlier in section 4.2, and also shown in Figure 6.3.1 below.

Since target facilities are so many and conditions are complicated, study was carried out systematically through three steps in the process of Risk Management. In the first two steps, the risks were defined through site survey and brainstorming (1Risk Factor Analysis) and the damages were estimated on the basis of fourteen risks (2Risk Assessment) so far. In this section of the study, the last stage is undertaken which includes formulation and proposing of countermeasures on concerned risks (3Risk Control).

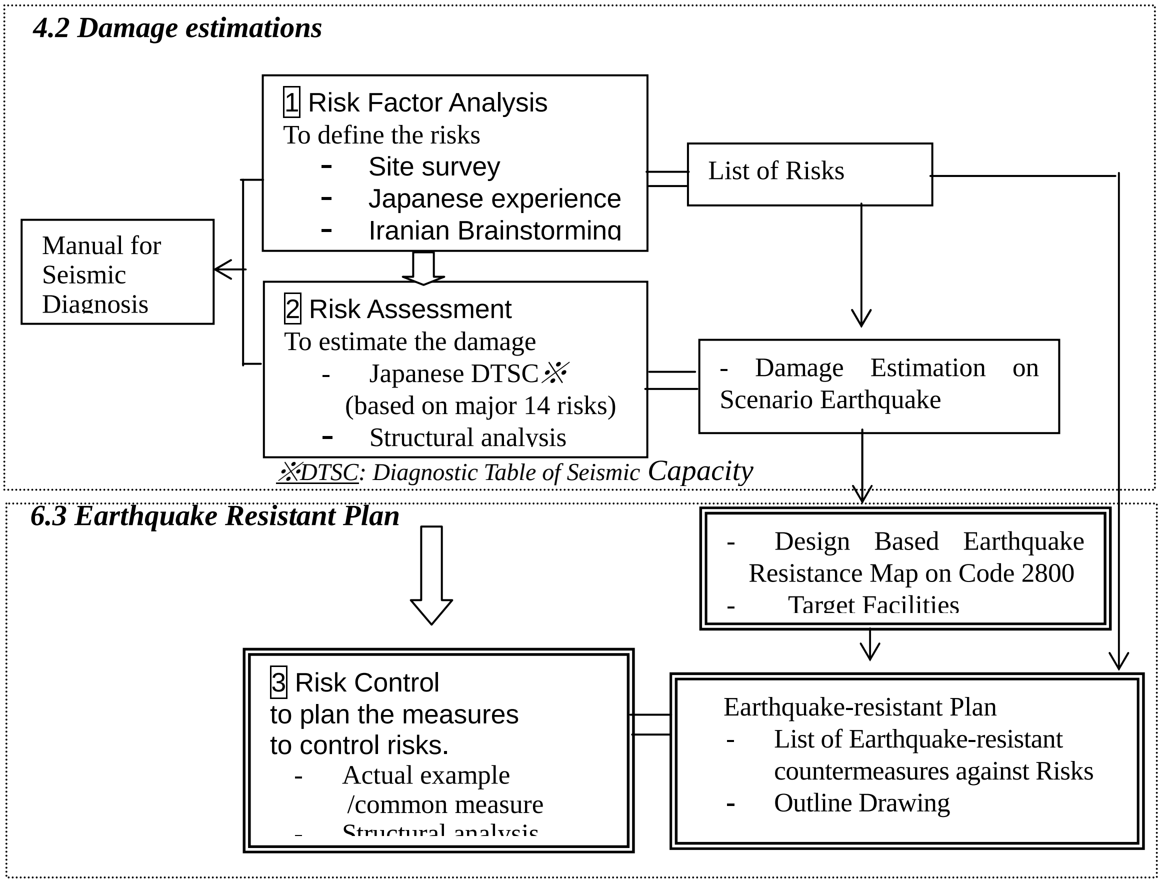


Figure 6.3.1 Flowchart of Related Tasks in This Section

6.3.1 General Conditions

(1) Design Conditions for Earthquake Resistant Plan

1) Principle of Target Facilities

Three of obvious facts are declared so far,

- One is that the facilities on fault in the case of North Tehran scenario earthquake of rare occurrence probability would be assumed seriously damaged.
- Another is that the Code on seismic design for building has been enforced for one decade and many facilities have been designed in accordance with Code 2800 after its enforcement.
- Also, TWWC intends to carry out seismic reinforcement of existing facilities.

Therefore we should consider that TWWC could transform smoothly to future design and construction stages. Hence, target facilities in study should be selected considering these situations, and we have categorized the target facilities as follows.

- Category A: The facilities on fault and other fragile facilities based on disastrous North Tehran scenario earthquake
- Category B: The fragile facilities evaluated by code 2800 on Design-Based Earthquake Resistance Map without condition of fault

a) Principle of the Measure for Facilities of Category A

Regarding the damage estimations on North Tehran scenario earthquake, only the facilities on fault are assumed seriously damaged. It is almost acceptable to design pipe on fault, but impossible for bigger items like building/tank. The countermeasure for building/tank on fault should be strengthening the foundation through measures of thick and expanded ground improvement against the ground displacement on faults. Moreover, considering the expenses on the physical measure against rare occurrence possibility of scenario earthquake, it is technically and economically difficult to implement physical measure. Therefore, the measures in terms of Minimization of Damage Effect such as back up with pipe/other neighboring facilities are applicable in the short term, and in the future it should be responded by relocation/re-planning of water supply system after the service of facilities would be fulfilled. If it is so, physical countermeasure against earthquake is not required for Category A.

b) Principle of the Measure on Facilities of Category B

On the other hand, Iran has a code 2800 for building, which came into effect legally after Roodbar-Manjil earthquake in 1990, and thereafter many seismic designed building have been designed/ constructed based on Code 2800. Therefore, in this Study, concrete measure must be analyzed in the same manner in terms of Minimization of Damage Occurrence.

Some considerations should be studied in terms of Minimization of Damage Effect though.

2) Approach on Study

As mentioned above, the strategy of countermeasure is diverse, and therefore approaches on study of countermeasure would be categorized into two, one is proper measure of Minimization of Damage Occurrence, and the other is Minimization of Damage Effect.

3) Evaluation Period

Seismic acceleration of 0.35G on code 2800, which is of a 100-year occurrence probability, is appropriate to be applied to public works in terms of facilities' service life (a 50-year span for RC structure), economical efficiency, and the acceptable level for the citizens, so that proper physical countermeasure would be carried out for seismic acceleration of 0.35G.

Therefore, as implementation program of physical countermeasure is mainly on the facilities of Category B, feasibility of program would be evaluated on the basis of 100-year span.

4) Design-Based Earthquake resistance Map

Toward the implementation of program, Earthquake-resistant design starts based on previous damage estimations on scenario earthquake and present situations of Design-Based Earthquake resistance Map on the condition of code 2800 shown in Figure 6.3.2 of which structural fragility is made by DTSC. Feature of Earthquake resistance Map is shown below.

According to the Map, as Generator Houses in WTP No.1 and No.2 are very fragile because of long span structure, measures would be required. Since other facilities are slightly fragile, measures should be carried out one by one starting from older facilities to the new ones considering their age and feasibility.

5) Disaster Map

Fire, gas poisoning or loss of human life might occur near the location of Generator, Transformer, Chlorine Dosing Equipment and Facilities on the cliff, and hence these facilities have potentially high-risk of disasters in case of earthquake occurrence.

When the earthquake-resistant measures are carried out, these disasters would be cleared up/mitigated, so the location of these risks would be marked on Secondary Disaster Map shown in Figure 6.3.3 for the awareness/knowledge in the study.

6) Ground/Soil conditions

Ground conditions, which were sorted out on study of Seismic Motion Analysis, were enough for the purpose of this Study. Several structural analysis have been performed to verify the DTSC and to prepare an outline of countermeasures against risks for reference.

In this study, for the structural analysis of required soil conditions of Pump house No.2, Reservoir No.6 and Pulsator in WTP No.2, since the specific soil data just on the ground behind the wall of the tank/pump chamber were not available, study team adopted sandy gravel on the basis of visual investigations and the data of categorized ground on study of Seismic Motion Analysis. As a consequence, friction angle was assumed 40 degrees on the safe side for the case of sandy gravel to calculate the active earth pressure during earthquakes.

In the near future, when the detail design of underground chamber/tank would be carried out, the specific soil data (N value, friction angle, uniaxial compressive strength, etc.) for the location behind the wall might be required. This is because the need of countermeasures is determined by the soil conditions.

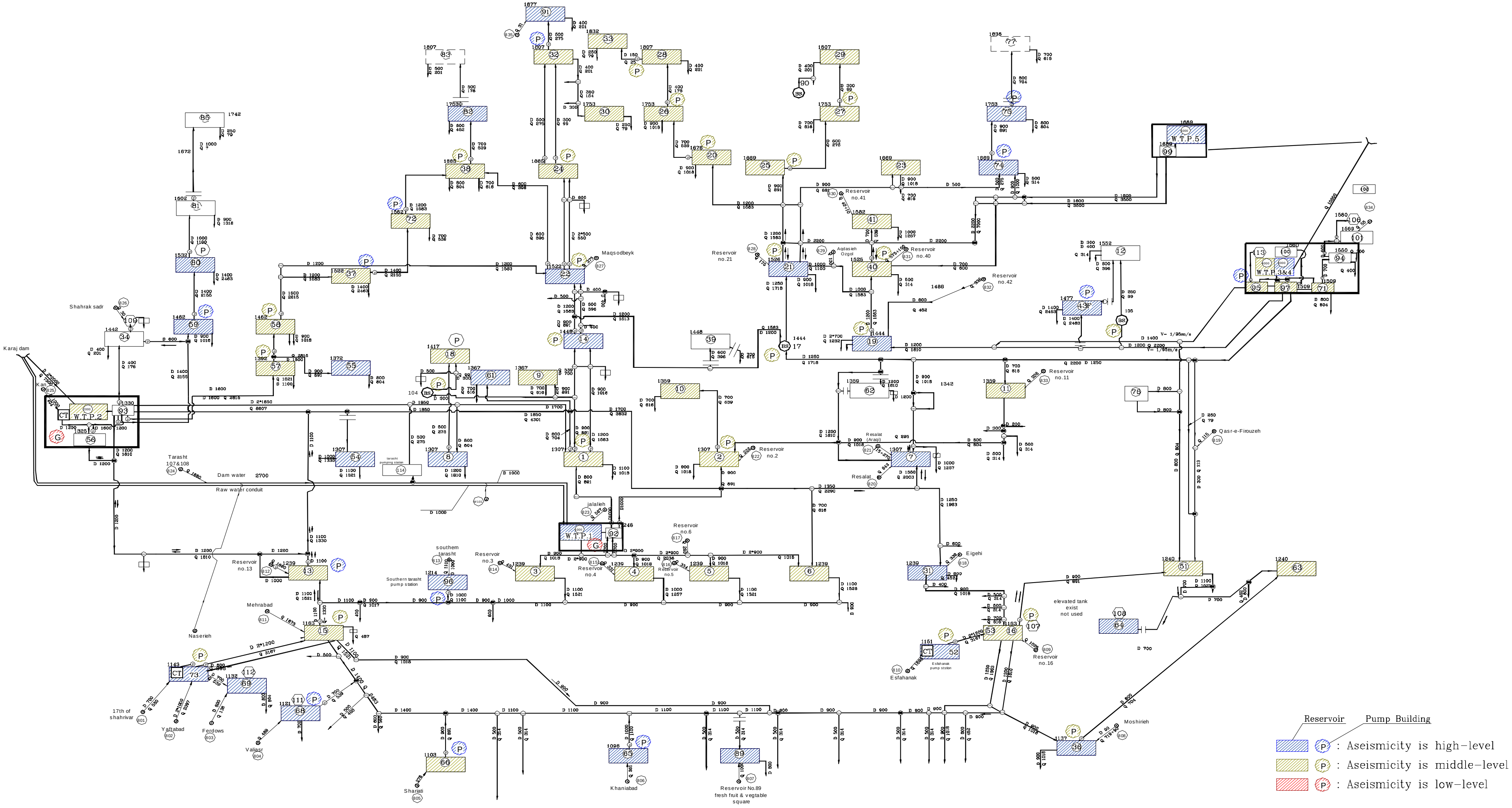


Figure 6.3.2 Design-Based Earthquake Resistance Map (present; A=0.35, without condition of fault)

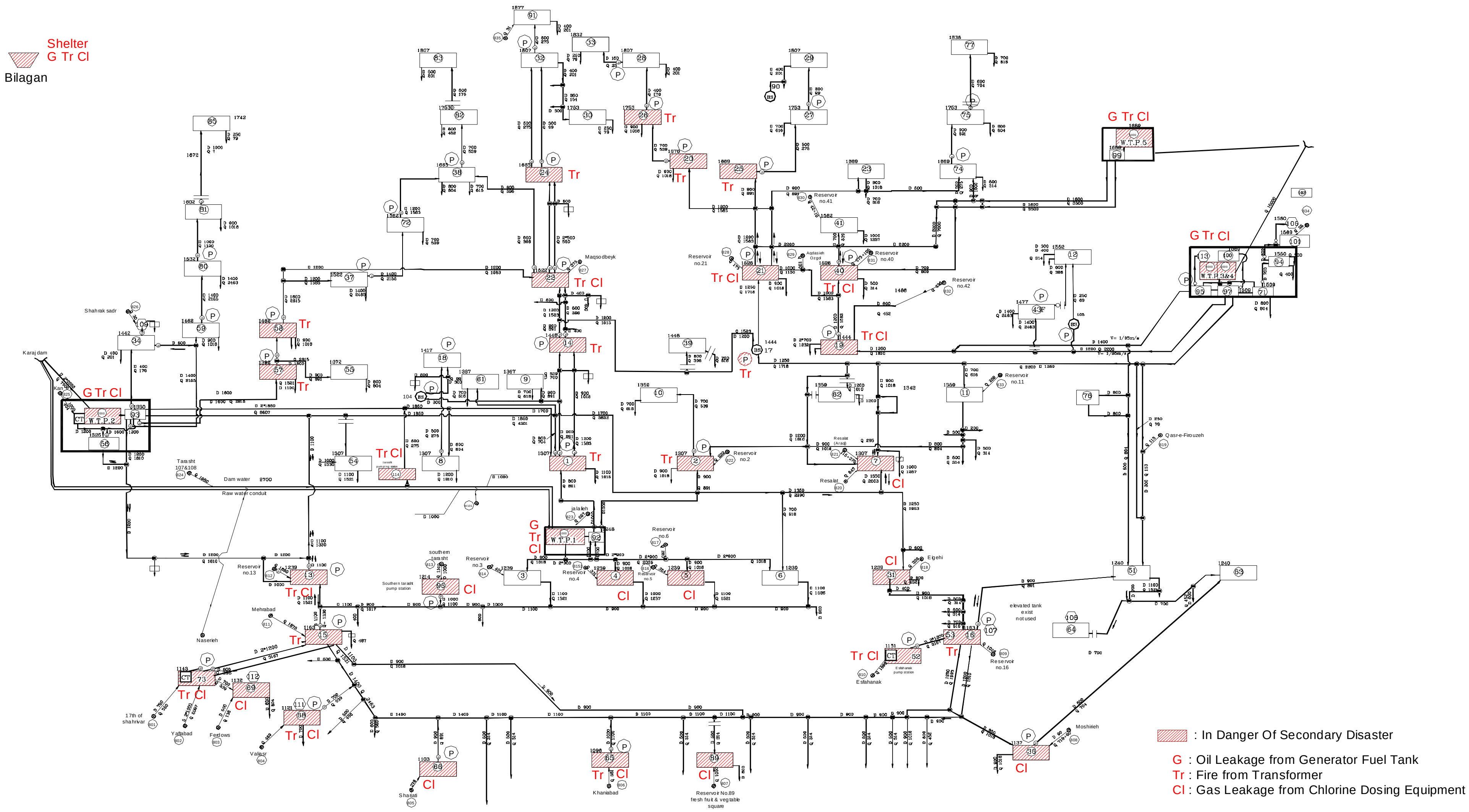


Figure 6.3.3 Secondary Disaster Map

(2) Study on facilities and priority of Countermeasures

As there are a large number of facilities, priority on implementation program would be presented on the basis of the site survey, damage estimations and earthquake resistance map, and study facilities shall be sorted out and target facilities selected as listed in Figure 6.3.4.

Seismic resistance			
small	･Facilities on Fault （Reservoir No.11, 14, 26, 71, 75, 77, 82, 95, 97, Filter&Pulsator on WTP No.4, Pulsator on WTP No.5） ･Surge tank (No.2, 22, 96) ･400V Pump Panel ･Sub-equipment (Battery, UPS, Flexible Pipe, Electric Post) ･Incoming Cable	･Transformer ･Non-structure member	･Generator House WTPNo.1 ･Generator House WTP2 ･ChloroneDosing Equipment
	･Deteriorated Reservior No.6, No.66 ･Deteriorated chamber of Filter on WTP No.4 ･Pump house No.1, 2, (14),15, 16, 17, 19, 20, 21, 22, 24, 36, 40, 52, 57, 58, 73 ･Oldest Reservoir No.1, 2, 3, 4, 5 ･Pulsator on WTP No.2 ･Fixation of Sub-equipment		･Bilagan Shelter ･Breezaway(WTP No.4) ･Emergency Post ･Fuel tank of Generator
	･Pump house No.25, (26), 27, 28, 38, 104, 105 ･Old Reservoir No.9, 10, (11), 13, 15, 24, (26), 29, 30, 32, (71), (95)		
big	･Relatively new Reservior (Reservoir No.16, 20, 25, 27, 28, 33, 37, 38, 40, 41, 51, 53, 57, 58, 63, 72, (97)) ･Facilities designed by code		
	small ←	Secondary Disaster	→ big

Figure 6.3.4 Target Facilities

Prioritizing and considerations /strategy are presented in *Table 6.3.1*, and summarized as follows

- The countermeasures on facilities which have high-priority are assumed as follows:
  - Building, in which people reside for routine work and important for sustaining human life
  - The structural members and equipment, the fragility of which were pointed out by visual

investigations and through structural analysis

  - The easy/simple countermeasures such as fixation of equipment, is highly economical.

- Since the effect of the damage of large Pump stations on water supply system is significant and widespread, important and large Pump Houses should be reinforced on a priority basis.
- Reinforcement of the Reservoirs ought to be carried out starting from an old facility one by one. As for the reinforcement of Reservoir, since these facilities have possibly high seismic resistance, so soil survey on backfilling behind the wall and sort-out of as-built drawing especially bar arrangement drawing ought to be carried out beforehand.
- The stabilization of a cliff or a slope is very important and of high priority, but this is an issue pending on specific study because geological survey of slope is not available, so in future geological survey must be carried out. However, the relevant countermeasures have been presented in Risk Control Chart (*Table 6.3.5*).

As the priority of implementation program is assumed in *Table 6.3.1*, concrete study case with outline drawing is selected from high-priority facilities as listed below;

- Generator house at WTP No.1
- Bileghan shelter
- Breezeway on Chemical house in WTP No.2
- Pump House No.2
- Reservoir No.6
- Pulsator on WTP No.2

At the same time, structural analysis of Reservoir No.23 has been carried out for the sake of its comparison with No.6.

Table 6.3.1 Concept of Priority and Study Facilities

Category	Concept of Priority	Abstracted Study facilities (*strategy/measure*)
Category B	1 **First Priority** of earthquake resistant plan is for **saving human life despite a disaster**.	
Category B	1.1 The building constructed before 1995 in which people stay	**Generator house at WTP No.1 & 2,** Bileghan shelter, Chemical house at WTP No.4, Emergency Post (*Reinforcement considering fragility*)
Category B	1-2 Avoiding gas poisoning	All Chlorination equipment (*Neutralization equipment &Emergency shutoff valve*)
Category B	1-3 Avoiding fire	All Generator Houses (*anti-flowout fence of fuel/fixation of transformer*)
Category B	1-4 Avoiding collapse of non-structure member/equipment	The Outer Marble Veneer of Chlorine House in WTP No.5, Breezeway on Chemical house in WTP No.2 and All Equipment
Category B	1-5 Stabilization of a cliff or a slope	(*This is a pending issue because geological survey of slope is required*)
Category B	2 **Second priority** of earthquake resistant plan is for maintaining the water supply system, prior to the important facilities and equipment.	
Category B	2-1 Halting the Advance of fragility	Reservoir No.**6**&No.66, Filter in WTP No.4 *(Repair of deteriorated members, and reinforcement)*
Category B	2-2 The fragile structure members of important facilities, such as Pump House, it is because the damage effect is large.	Pulsator in WTP No.2 Large Pump House No.1, **2**, (14), 15, 16, **17, 19**, 20, 21, 22, 24, 36,40, 52, 57, 58, 73, Oldest Reservoir No.1, 2, 3, 4, 5
Category B	2-3 Secured sources of Power supply	All Pump station *(Duplication of Power Source/Generator)*
Category B	3 **Third priority** of earthquake resistant plan is for maintaining the water supply system	
Category B	3-1 Old structures not nominated above, constructed before 1970	Reservoir No.9, **10**, (11), 13, (14), 15, 24, (26), 29, 30, 32, (71), (95) Pump house No.25, **104, 105**, (26), 27, 28, 38 *(These facilities have possibly high seismic resistance, so soil survey and sort-out of as-built drawing should be carried out)*
Category A / Category B	4 **Low priority**	
Category A / Category B	4-1 Old structures not nominated above, constructed before 1995, relatively new facilities.	Reservoir No. 16, 20, 25, 27, 28, 33, 37, 38, 40, 41, 51, 53, 57, 58, 63, 72, (97) *(These facilities have possibly high seismic resistance, so soil survey and sort-out of as-built drawing should be carried out)*
Category A	4-2 Relocation of the facilities on fault *(In the short term, facility corresponds by backup with flexible piping, bypass or other related neighboring facilities, from the viewpoint of minimization of damage effect on the System)*	-Filter and Pulsator at WTP No.4, Pulsator, Chemical House and Chlorine House in WTP No.5, Reservoir No.11, 14, 26, 71, 75, 77, 82, 95 and 97 *(Facilities in WTP No.5 and Reservoir No.75 and 82 are designed by new code, so resistant to a 100-year return earthquake)*

Note:

- *(11) is the facility laid on fault.*
- *Reservoir No.6, 10, Pump house No.2, 17, 19, 104, 105 and Generator house on WTP No.1&No.2 are slightly fragile as facilities on Category A.*

6.3.2 Measures for Minimization of Damage Occurrence

(1) General

Study of measures for minimization of damage occurrence is a proper earthquake -resistant plan, and some countermeasures would be based on structural analysis, the software/method of analysis is as follows;

- For structural analysis the software, namely SAP 2000 ver.8, is applied.
- Regarding the equipment study, there is no Iranian code for the method of strength analysis of foundation bolt, so Japanese code was referred to, in the document titled "Seismic Design & Construction Guidelines for Building equipment (1997)" by the Building Center of Japan.

(2) Earthquake-resistant Plan on Tank

1) General and Present Situations

Study team has considered the following case study to define the problem clearly.

The selected structures for Study cases are Reservoir No.6 and Pulsator at WTP No.2, these are obviously fragile and have high priority, and structural analysis has been carried out by acceleration 0.35G.

For comparison, Structure of Reservoir No. 23 is analyzed in the case of biggest acceleration 0.691G on scenario earthquake of North Tehran Fault for reference.

Table 6.3.2 Present Earthquake Resistance

	Reservoir No.6	Pulsator at WTP No.2	Reservoir No. 23	
Construction Year	1955	1963	1970	
Acceleration	0.35	0.35	0.35	0.691
Slab	OK	-	OK	**NG**
Column	OK	-	OK	OK
Wall (internal face)	OK	OK	OK	OK/**NG***
Wall (external face)	**NG**	**NG**	OK	OK/**NG***
Foundation	OK	OK	OK	OK

** On two-dimensional plan, short side of wall is safe, but long side of wall is not safe.*

The result of analysis reflected that the estimated damage is not so disastrous on the basis of structural analysis, and required countermeasure would not be so large-scale.

On the basis of design acceleration 0.35, Reservoir No. 23 is safe, but small area of wall on Reservoir No.6 and Pulsator are slightly not safe due to hammering of active earth pressure during earthquakes.

Generally speaking, from the aspect of the ground condition, when it is extremely good, the ground which holds tank tightly, unifies with tank, so that the ground and tank move together in the case of occurrence of the earthquake, and the tank does not receive strong hits and damages.

Through the analysis, it is confirmed that the old tank located in southern area is slightly fragile but the relatively new tank located in northern area is strong against earthquake. This fact is the advantageous feature/good news regarding damage in the scenario earthquake of North Tehran Fault, which should be considered as a priority in implementation program.

2) Reservoir No.6 and No.66

There are two countermeasures for Reservoir No.6, one is refurbishment of deteriorated ceiling of compartment in order to secure the structural reliability against earthquake, and the other is the reinforcement of wall.

Regarding the structural member, slabs and columns have secured earthquake resistance, but only reinforcing bar on the external face of wall is not sufficient. The bottom slab is stable because the bearing capacity is sufficient.

a) Proposed Reinforcement

Since Ground condition is very good in Tehran, minimization of countermeasure activities is possible. As for the study case, only reinforcing bar (area= 6.2 cm^2) of the external wall is not sufficient. On the contrary internal bar area is 34.9 cm^2, so additional external RC wall on the existing wall in *Figure 6.3.5* is suitable for such cases. The thickness of the additional wall should be 20cm with reinforcing bar of D16@125. As the ground is firm and dense, countermeasures could be executed at low budget. However, soil survey should be carried out on the present ground/soil conditions before the execution of reinforcement.

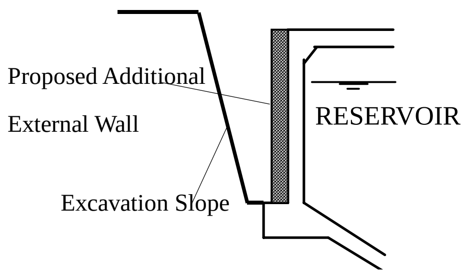


Figure 6.3.5 Reinforcement of Reservoir

b) Proposed Refurbishment

Refurbishment should be made by repair of the deteriorated concrete to secure the earthquake resistance and improvement of ventilation.

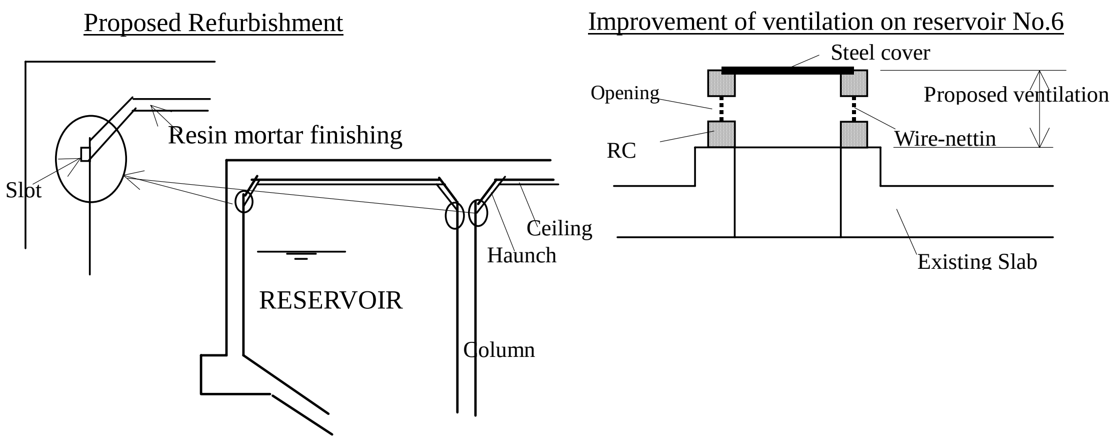


Figure 6.3.6 Refurbishment of Reservoir

Deterioration of inside compartment due to insufficient ventilation was observed in Reservoirs No.6 and No.66. Before refurbishment of that, thorough investigation (the number of exposed bar) is required. Design for refurbishment at haunch and ceiling of Reservoir No.6 would be proposed just for reference.

Generally, execution procedures for refurbishment is as follows

- Stripping the deteriorated concrete off by high pressure washing
- Rust resisting paint application for corroded reinforcing bar / attached bar
- A slot is cut to concrete in the edge of finishing.
- Primer application
- Three times as much of resin mortar finishing by Trowel finish for 2 cm concrete cover
- Improvement of ventilation

3) Oldest Reservoirs

For the cases of the oldest Reservoirs from No.1 to No.5, the conditions of which were explained in the previous general clause, their wall might be reinforced in the same manner as the proposal of additional external wall for Reservoir No.6.

Though we consider these countermeasures in implementation program, we anticipate TWWC to carry out further study including the soil survey, preparing the present drawings of bar arrangement and structural analysis, as soon as possible.

4) Other Reservoirs

On the basis of DTSC, Reservoir in deep-water or semi-buried is assumed middle rank in terms of earthquake resistance.

We could not specifically evaluate the seismic resistance, because it was difficult to survey all tank's bar arrangements and to grasp the tendency of bar arrangement. So we anticipate TWWC to carry out further study, which shall include the soil survey, preparation of the present drawings of bar arrangement and structural analysis in near future, after the measures are implemented in the oldest Reservoirs.

We will consider these situations in implementation program.

5) Tank of WTP

Generally speaking, circular sedimentation tank or rectangular tank with a depth of 3m or less has high earthquake resistance, but Pulsator's wall in WTP No.2 is not only deep but also thin (25cm). Therefore, the deepest part of the wall which experiences active earth pressure during earthquakes, has led to insufficiency of wall thickness/reinforcing bar.

On the other hand Pulsator in WTP No.3 and No.4 are of the same water depth as No.2, but the wall is 40cm thicker than No.2, so were analyzed as safe.

Therefore reinforcement of Pulsator in WTP No.2 is only proposed.

Moreover, improvement of leakage condition in Filter in WTP No.4 is required; the problem is small in present situation but is very much likely to grow to alarming level in forthcoming earthquake, so countermeasure would be proposed.

a) WTP No.2 Pulsator

Small area of wall and foundation of Pulsator should be reinforced as shown in *Figure 6.3.7*.

When the reinforcement is carried out, it would be better to fix the trough for water catchments together.

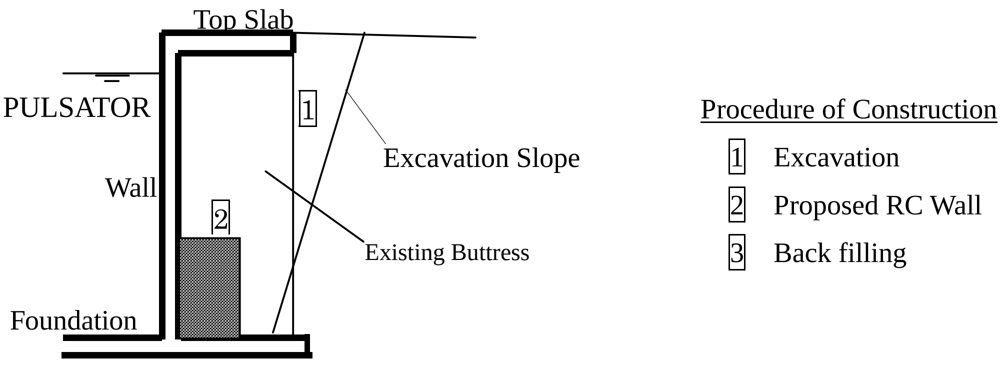


Figure 6.3.7 Reinforcement of Pulsator

b) Filter at WTP No.4

Regarding leakage of water from the Filter at WTP No.4, it might lead to a big problem in response to an earthquake.

While the problem is small now, it should be solved to secure functions in case of occurrence of the earthquake.

Since the foundation of structure is already stabilized and there are many expansion joints compared with the other WTP, the removal of a part of Expansion Joint and the unification of a part of structures of the basement in Filter house would be proposed.

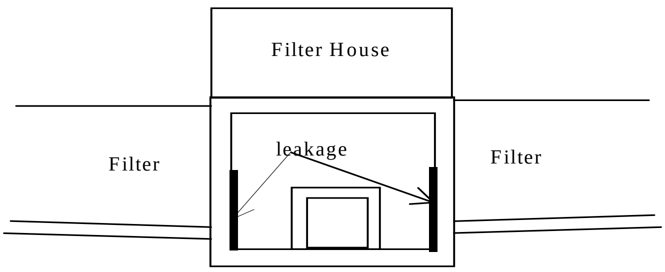


Figure 6.3.8 Section of Filter

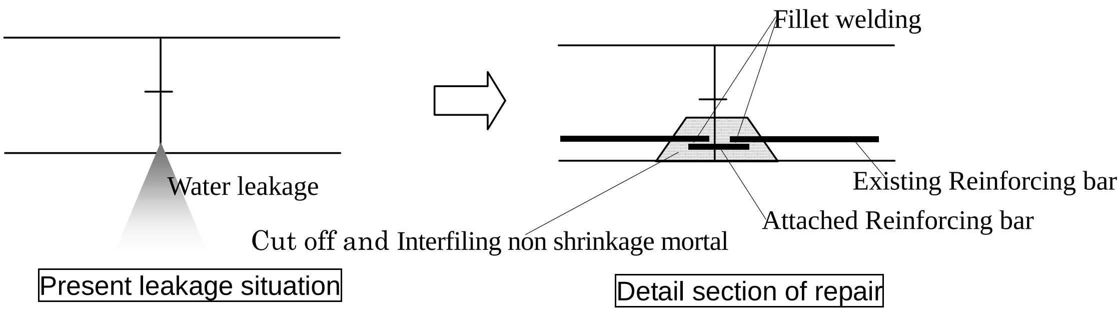


Figure 6.3.9 Improvement of Leakage on Filter

(3) Earthquake-resistant Plan for Buildings

The priority of countermeasure for the buildings where people reside for routine work is higher than tank, and reinforcement for building is relatively easy to implement and at affordable construction cost, so in Japan the reinforcement of almost all of the public buildings have been finished in a short time after the regulation was enforced.

Therefore, in Tehran also reinforcement of buildings should be implemented in a short time.

1) Reinforcement method on buildings of RC structure

In Japan there are many reinforcement methods as described in *Table 6.3.3* under Japanese special circumstances. On the other hand the premises in Tehran water supply facilities afford to be constructed by any method, so Shear Wall of RC method by cast in place is adopted because of its low construction cost.

Though other alternative is Brace method, Iranian method of reinforcing wall is filling by use of brick into vacancy, as we intend to reinforce brick wall simultaneously, RC wall is suitable for our intention.

2) Pump House

Installation of Shear Wall and Reinforcement of brick wall for Pump House are as follows

- The fragile member is reinforced by RC shear wall with the aim of reducing horizontal deformation. As a consequence, deformation of frame is restricted and the risk of collapse of brick wall would be reduced.
- Since it was manifested in Bam earthquake that the brick wall without tie attachment (*Figure 6.3.12*) would collapse, tie is essential on masonry for securing shear strength. If the brick wall of target building is not installed with tie, wall should be fixed somehow. So fixation of brick wall to clip by steel plate, as shown in *Figure 6.3.11*, would be proposed. (also refer to *Figure 6.3.13*)

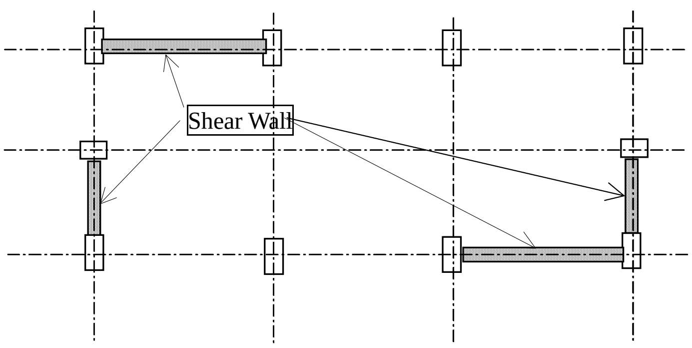


Figure 6.3.10 Plan of Arrangement of Shear Wall

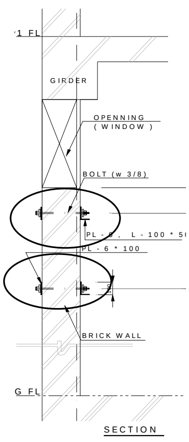


Figure 6.3.11 Fixation of Brick Wall

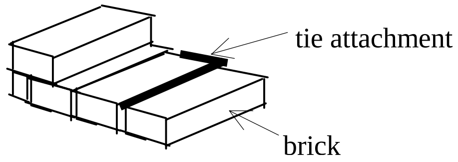


Figure 6.3.12 Tie Attachment

3) Emergency Post

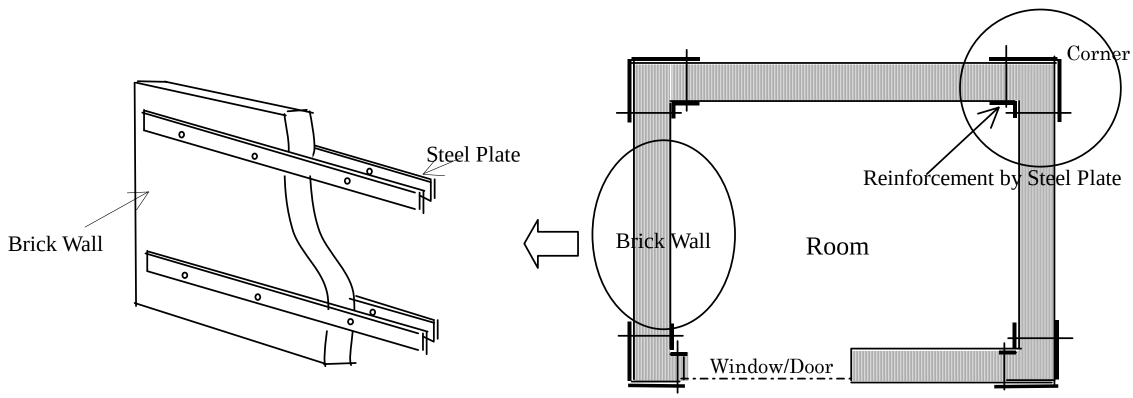
As requested, supplementary survey of Emergency Post was performed for preparation of earthquake-resistant plan.

There are 18 Emergency Posts that are important for emergency repair on earthquake. Five Posts had been surveyed; they are four Masonry Houses (Zargandeh, Niavaran, Amir Abad, Reservoir 54) and one Steel Structure House (Shahrake Gharb).

Masonry Houses, Earthquake resistance capacity of which could not be evaluated, are currently occupied by so many workers, so they should be reinforced in the manner of the proposed idea as shown in *Figure 6.3.13*.

Steel Structure House would not intensively collapse, so could be renewed in the future.

It is not because of RC Structure, but size of the building might be smaller than Chemical House at WTP No.4. Chemical House at WTP No.4 has earthquake resistance without shear wall, so earthquake resistance of Emergency Post Shahrake Gharb would be secured.

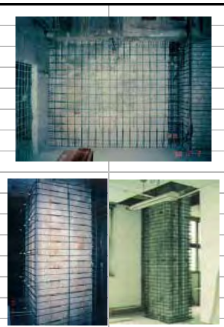
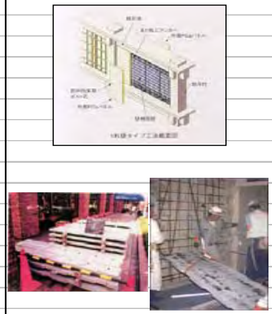
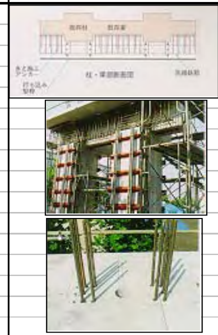
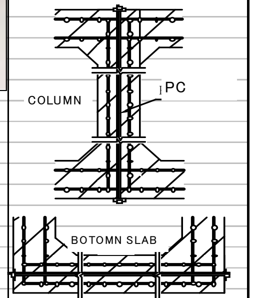


Fixation of Brick Wall

Reinforcement at Corner of Masonry House (plan)

Figure 6.3.13 Fixation of Brick Wall and Reinforcement of Masonry House

Table 6.3.3 Reinforcement Methods in Japan

METHOD		RC METHOD: CAST IN PLACE	RC METHOD: PRESTRESSED-CONCRETE MEMBER	CARBON FIBER SHEET REINFORCEMENT	BRACE	EXTERNAL FRAME	CAST-IN-PLACE PRESTRESSED CONCRETE
FIGURE							
BRIEFING OF METHOD FOR REINFORCEMENT		The rebarring work of a main reinforcement and the shear reinforcement on the arround of the existing column is carried out , and improves resistance to stress and deformation.	The small precast unit which used lightweight concrete (about 1.3 specific gravity) is manufactured and is installed inside of the building. A precast unit is installed by a required anchor and a rebarring work, and a opening is filled up shrinkage-compensating mortar into it .	The carbon fiber which is excellent in a light weight and corrosion resistance, is stuck on the existing member face, and reinforces member with high intensity, specifically increase in the shear strength of a column or a beam component and improvement in deformation resistance nature are achieved. Execution procedures: 1. Surface treatment on the surface of concrete 2. Primer application 3. Adhesive-bond(resin) application 4. Attachment of a carbon fiber 5. Resin application 6. Finishing (the material of construction is chosen if needed)	Steel frame brace with a frame (stud) is installed and fixed by anchor on the existing column&beam. Regarding installation, after attaching a spiral reinforcing bar on the arround of a brace, shrinkage-compensating mortar is poured in a opening.	Additinal new RC structural frame is installed outside of exsisting structural frame. Execution procedures: 1.Anchoring on the exterior face of existing column&beam. 2.Placing of reinforcement 3.Formwork 4.Concreting in fluid and lightweight aggregate concrete	PC steel is inserted into the hole of existing member which is drilling in advance. Since improvement in axial tension can be aimed at, increase in a shear and flexural strength and improvement in deformation resistance nature are expectable. This is applicable for undergroung chamber/tank.
FEATURE		■Most commonly used method ■Long construction period requires and a work environment is not so good for worker. ■Skill requires for anchoring of a main reinforcement.	■Site operation is easy and construction period is shortened.	■There is almost no increase in a weight or a size after reinforcement. ■Since the material is light, handling is easy and a construction period is shortened. ■It is suitable also under corrosive atmosphere, such as salt damage, for the incorruptible material.	■A problem arises in steel frame fabrication and on-site carrying-in /anchoring accuracy. ■A construction period is early if the above problems do not occur.	■Since it is constructed at outside of a building, indoor routine work is possible.	■Since PC steel is inserted from the outside , function of chamber/tank is retained.
ADVANTAGE	PROOF STRENGTH	wall ○ column ○	○	○	○	○	△
	PROOF STRENGTH & TOUGHNESS	wall ○ column —	○	○	○	○	△
	TOUGHNESS	wall — column ○	—	○	—	○	△
APPLICATION	BEAM	○	—	○	—	—	○
	WALL	○	○	—	○	○	○
	COLUMN	○	—	○	—	—	○
	SLAB	○	—	—	—	—	○
	HAUNCH	○	—	○	—	—	

Note: As this table which has been created on actual design and commonly used in Japan, was translated as a sample in this study, there might be possibility that some of the above methods could not be applied to any case in Iran.

4) Generator House

Shear wall in Generator Houses of WTP No.1 & No.2 would be proposed, same as in case of Pump House, refer to *Figure 6.3.10*.

The fragile member of Generator Houses at WTP No.1 & No.2 should be reinforced by RC shear wall to reduce horizontal deformation. As a consequence, shear strength should be improved, deformation of frame is restricted, the risk of collapse of brick wall should be reduced and mitigation of fire should be provided for.

5) Breezeway

End Support of Breezeway in Chemical house in WTP No.2 would be proposed.

Bar arrangement drawing of Breezeway could not be found out, but the end of Breezeway would be acted upon by twisting moment of structure, so end supports of Breezeway on both sides would be required to prevent falling.

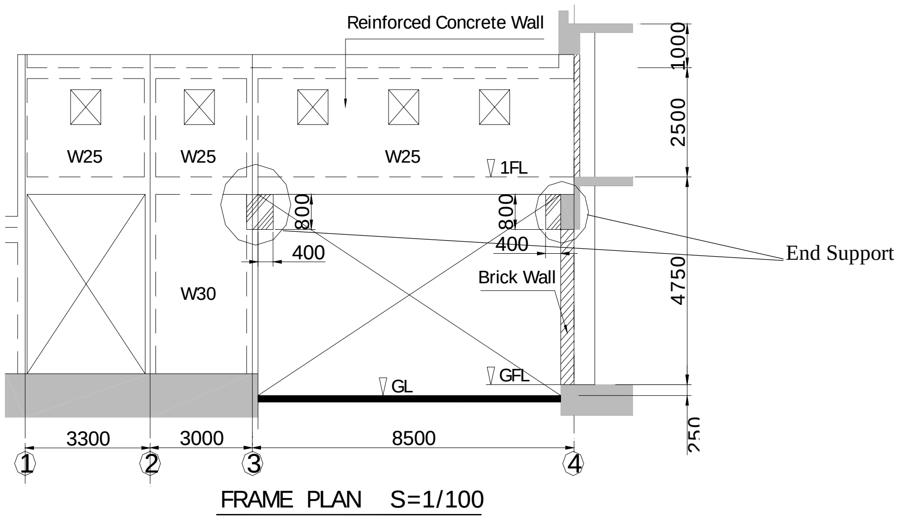


Figure 6.3.14 End Supports of Breezeway

6) Bileghan Intake Shelter

There is a defensive wall on the south face of shelter, but not on the north face. When the cliff collapses, the rocks will block entrance or might damage resting place, which might lead to an accident resulting in injury or death. Therefore, RC wall should be constructed on the north face of the shelter.

7) Chemical Factory

Since detail drawing could not be found out, structure analysis was suspended. If this building would be used somehow, large-scale refurbishment would be required as follows;

- Rust resisting paint application for corroded steel, which composes principal members, should be made.
- Reinforcement by bracing the principal members of structure should be made.

– Roof, external wall, floor, internal wall and fixtures/furniture should be installed/replaced by new materials, roof should be installed by lightweight materials and setting heat insulating materials.

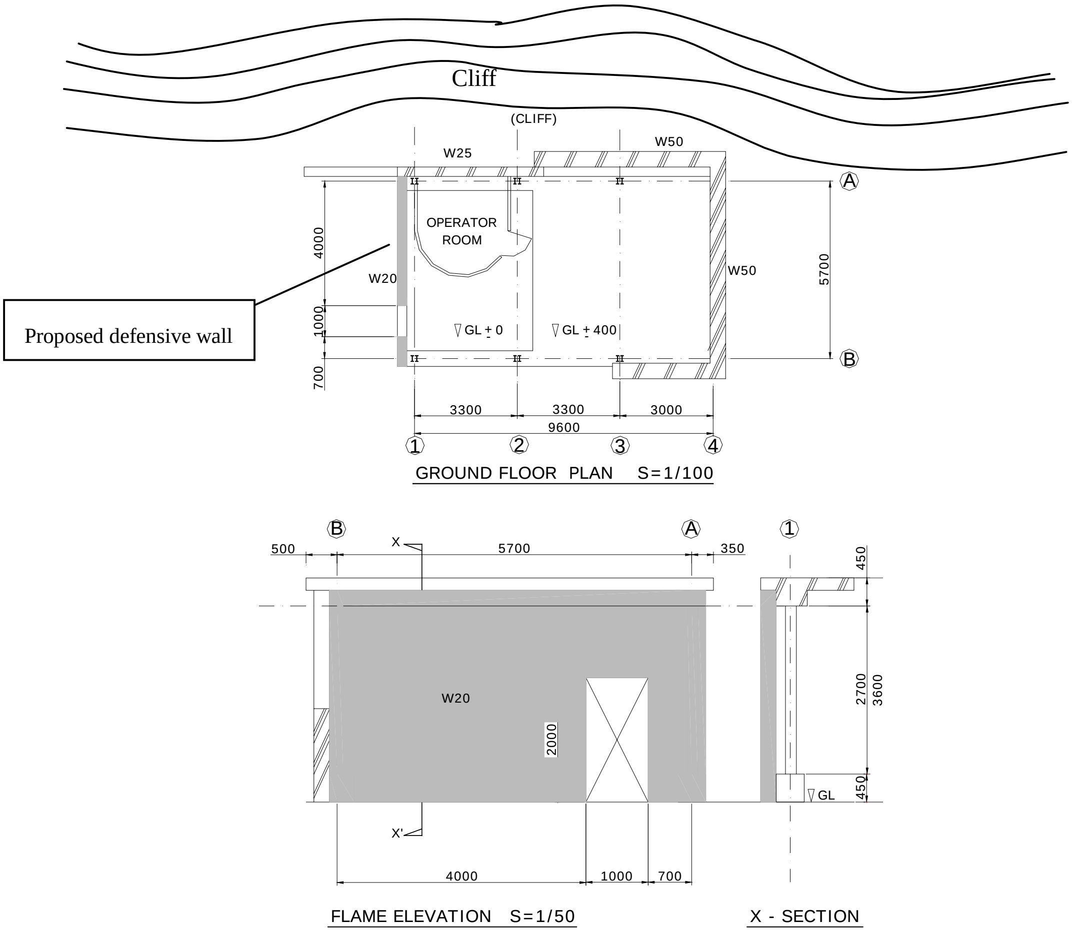


Figure 6.3.15 Defensive Wall on Bileghan Shelter

(3) Earthquake-resistant Plan on Mechanical and Electrical Equipment

Main typical equipment such as Pump is installed firmly, but fixation of sub-equipment is not so good. Therefore, as countermeasures for minimization of damage occurrence on equipment, such as fixing the equipment (chlorine cylinder, transformer, battery, UPS, 400V pump panel, etc) and installation of pipe or cable with flexibility and support for surge tank, should be implemented.

1) Support for Surge Tank

This countermeasure is proposed for Reservoirs No.2, No.22, No.96. *Figure 6.3.16* shows countermeasure plan at Reservoir No.22. Countermeasure for Reservoir No.2 is reported in the Appendix.

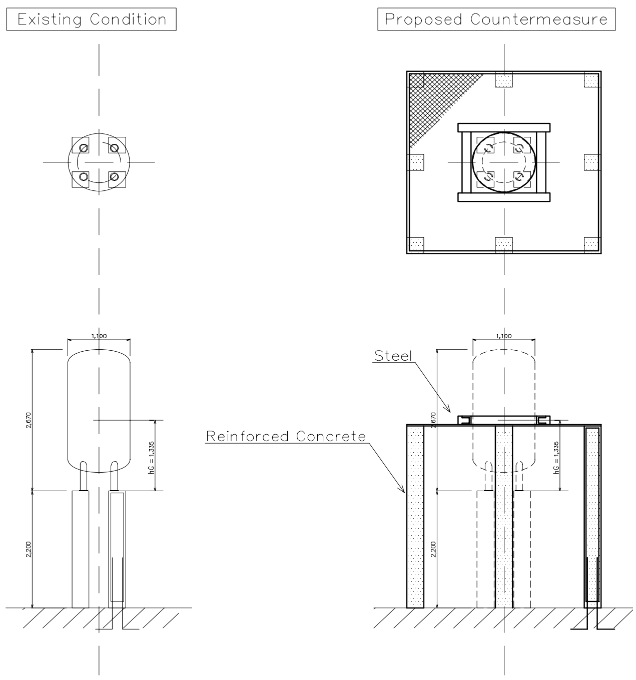


Figure 6.3.16 Countermeasure at Reservoir No.22

2) Fixation of Chlorine Cylinder

This countermeasure is proposed for WTPs No.1, No.2, No.3, and all the chlorine dosing stations. *Figure 6.3.17* shows proposed countermeasure at typical WTP and chlorine dosing station.

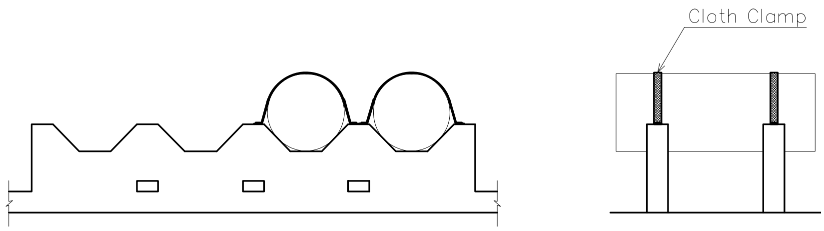


Figure 6.3.17 Countermeasure at Typical WTP and Chlorine Dosing Station

3) Fixation of Transformer, Battery, UPS, 400V Pump Panel

This countermeasure is proposed for almost all the WTPs and pump stations. *Figure 6.3.18* shows the method of measure taken for typical transformer. Other countermeasures are reported in the Appendix. Steel stage of Pump Panel at Station No.72 looks fragile, so brace of column would be proposed in the Appendix.

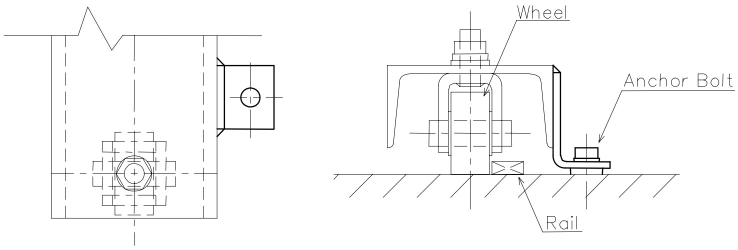


Figure 6.3.18 Countermeasure for Typical Transformer

4) Installation of Flexible Pipe

To equip fuel feeding pipe with flexibility, it is necessary to install flexible pipe on generator equipment. *Figure 6.3.19* shows proposed countermeasure at typical generator equipment. Other countermeasures are also described in the Appendix.

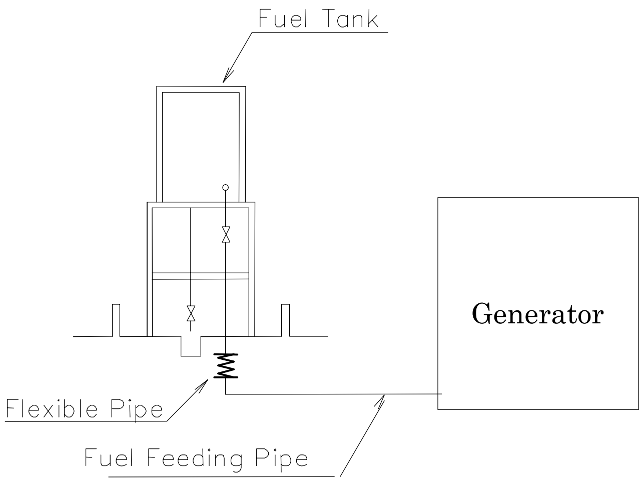


Figure 6.3.19 Typical Countermeasure of Fuel Feeding Pipe

6.3.3 Measures for Minimization of Damage Effect

(1) Outlook of Minimization of Damage Effect of the System or Secondary Disasters

- Avoiding the secondary disasters, which is an objective of Minimization of damage effect on facilities structure and equipment, would be provided for by the proposed countermeasures.
- Multiple compartments or bypass of inlet to outlet on Reservoir would help to reduce the damage effect on water supply system.
- Duplicate channel on WTP would be evaluated with the viewpoint of minimization of damage effect to water supply system.
- Structural reinforcement of Pump house or Building, which is an architectural structure, should be able to be measured with the viewpoint of minimization of damage occurrence, and it has also additional objective of minimization of damage effect, because the structural damage might lead to physical injury.
- Fixation of non-structural members such as degraded windowpane or outer wall finishing material

mitigates physical injury. Therefore, improvement of safety of non-structural member should be studied here.

- Regarding Mechanical and Electrical Equipment, Standby Pump or Duplication of Power Source would be evaluated from the aspect of minimization of damage effect to water supply system.
- Fire, gas poisoning or loss of human life would occur at the location of high-risk facilities: generators, transformers, chlorine dosing equipment and facilities on the cliff. On the measures and implementations of these facilities, study team prepared Secondary Disaster Map shown in *Figure 6.3.3*, intended to mitigate these risks.
- Facilities on Fault should be relocated in the future, but should correspond by the means from the aspect of minimization of damage effect to water supply system.

(2) Present situations on Minimization of Damage Effect

1) Tank

a) Reservoir

Main Reservoirs are installed with duplicate compartments as shown in the plan of Reservoirs in a report named "Report of Available condition of Tehran Water Network Appendix 3" In this report plans of forty six Reservoirs are available. Moreover many Reservoirs shown in this report have bypass from Inlet to Outlet.

Table 6.3.4 Number of Compartment in Reservoir

Reservoir name	Compartment No.	Reservoir name	Compartment No.	Reservoir name	Compartment No.
No.1	4	No.18	1	No.36	3
No.2	2	No.19	2	No.37	2
No.3	3	No.20	2	No.38	2
No.4	3	No.21	3	No.40	2
No.5	3	No.22	4	No.41	2
No.6	3	No.23	3	No.51	2
No.7	3	No.24	4	No.53	1
No.8	3	No.25	2	No.56	3
No.9	2	No.26	4	No.57	2
No.10	2	No.27	2	No.58	2
No.11	2	No.28	2	No.62	1
No.12	2	No.29	2	No.63	2
No.13	3	No.30	3	No.89	2
No.14	3	No.31	3	No.73	4
No.15	4	No.32	2	No.17	No Reservoir
No.16	3	No.34	2		

Reservoir No.11, 14 and 26 are on Fault.

b) Tank of WTP

Treatment tank is divided into duplicate tanks. Inlet channel is one or two lines for one treatment plant.

2) Building

Nonstructural members such as windowpane or marble veneer are deteriorated, and might lead to death or injury of human beings.

3) Mechanical and Electrical Equipment

The present situation is shown below

- Incoming cable is already duplicated at almost all the pump stations
- Standby pump is installed at each pump station.
- Emergency generator is not installed at each pump station.
- Safety equipment for chlorine dosing equipment is not installed, that may cause gas poisoning.
- Anti-flowout fence for fuel tank does not exist, that may cause fire.
- Transformer is not fixed, that may cause fire.

(3) Countermeasures on Tank

1) Reservoir

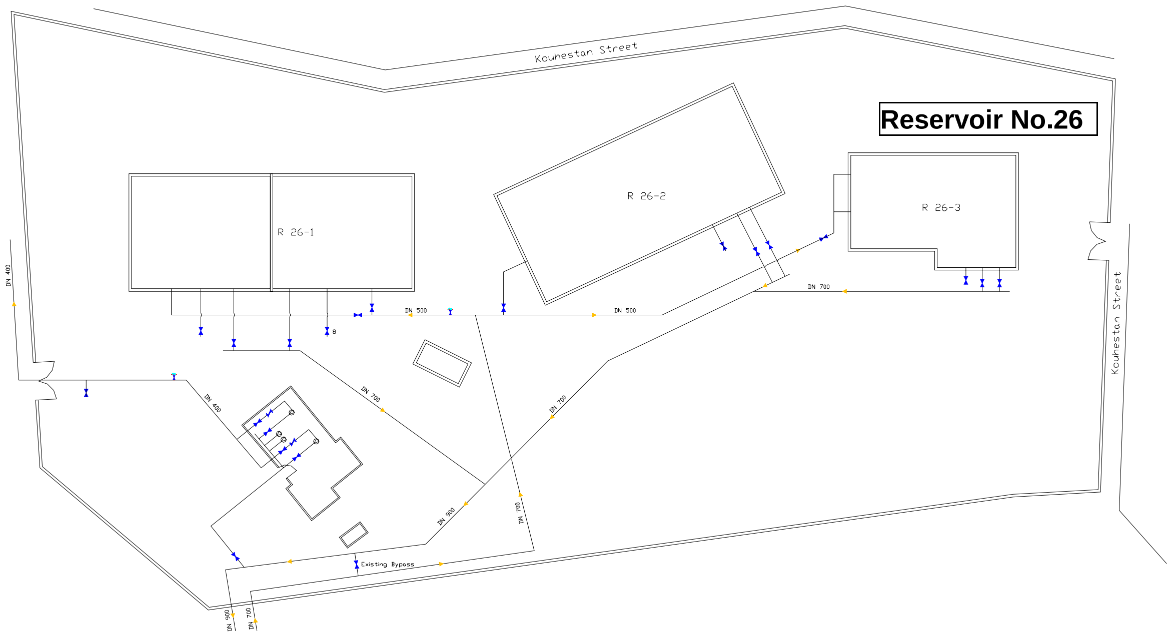
There are duplicate compartment in most Reservoirs, and probability of simultaneous damage of all these compartments is small, so if Reservoir is damaged, the effect would be small/minimized. But when a compartment is damaged, other compartments also lose water, so it is better to install shutoff valve in terms of the risk control.

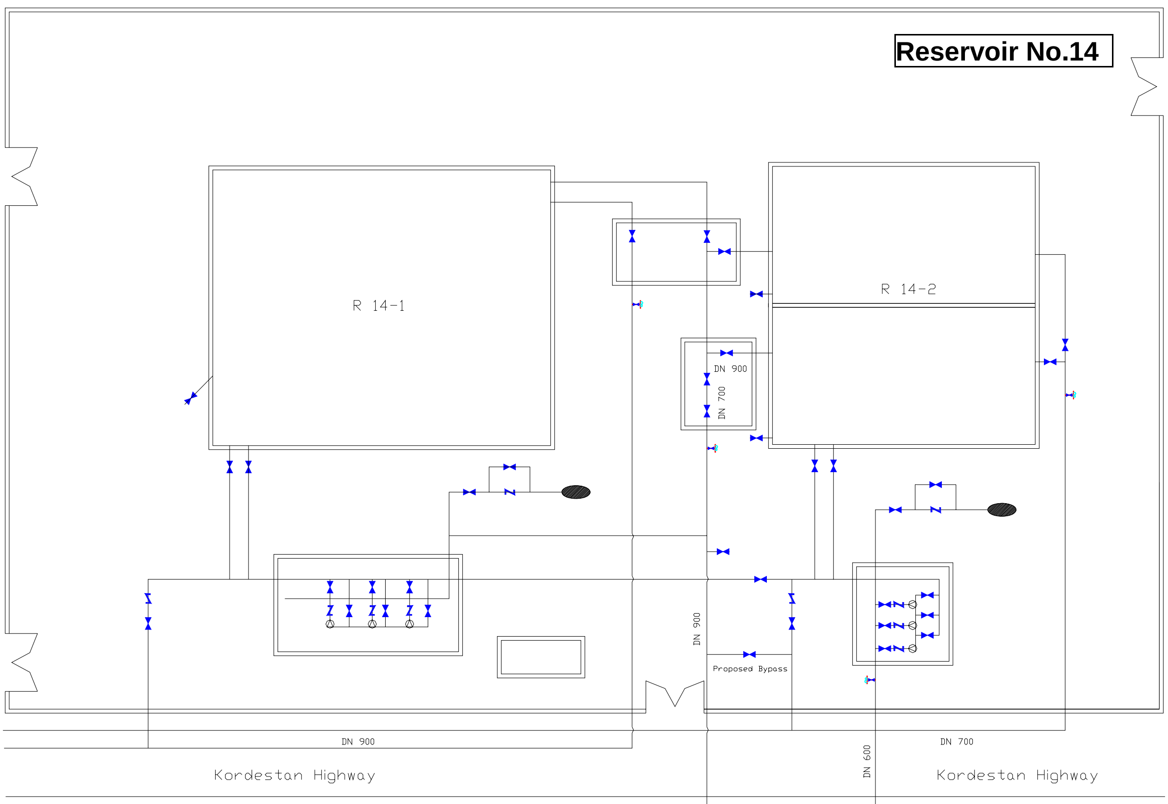
Moreover some Reservoirs have bypass from Inlet to Outlet. If all compartments are damaged, bypass could minimize the effect on water supply system.

In the case of single compartment on a Reservoir, possible measures for minimization of damage effect are as follows;

- Reservoir No.18: This is a small structure. Since a small structure has high earthquake resistance, damage effect would not be significant.
- Reservoir No.53: Near this reservoir, there is backup Reservoir No.16 which has three compartments.
- Reservoir No.62: This is Break Pressure Tank, not Reservoir, so damage is not a threat to water supply system.

Reservoir on Fault is also supported by the means of duplicate compartments, bypass or backup of other Reservoirs, and effect of structural damage to water supply system is thus minimized. In *Figure 6.3.20* the situations of bypass of Reservoir No.26 and No.14 on fault is shown for reference.





Bypass on Reservoir which has no bypass, would be proposed on implementation program of pipe line.

Figure 6.3.20 Bypass of Reservoir on Fault

2) WTP

Treatment tanks are divided into several tanks, so damage effect would be mitigated. If inlet channel has duplicate line, damage effect would be further minimized.

- WTP No.1: Only one inlet channel is placed from inlet chamber to Accelerator, inlet channel's water level is high, which means no margin. So one more line is desired, but there is no space for line construction. However, space for bypass line from inlet chamber to filter should be secured, if possible in terms of water quality, so that bypass would be effective.
- WTP No.2: Treatment Plant is divided into two, so damage effect would be mitigated.
- WTP No.3, No.4: Two lines are secured including both treatment plants, so damage effect would be mitigated.
- WTP No.5: If half of the plant would be expanded, damage effect would be mitigated.

(3) Countermeasures on Building

1) Window

Windowpane would crash and fall down due to degraded cushion (face putty or cap sealant) of windowpane. Therefore, if possible, it's better to replace the window including the frame.

At least, shatter-resistant film should be pasted on windowpane in order to mitigate risk of glass breakage, scattering and injuring human life.

2) Door

Sliding hanger door for outer door is adopted as an earthquake-resistant measure, considered better than swinging door.

On the other hand for inner door, wooden swinging door is adequate because when people are trapped inside, it could be broken and people can escape.

3) Outer Wall Finishing

As pointed out in the chapter on reconnaissance already, heavy outer wall finishing material such as marble veneer could cause injury or death. Installation of large marble veneer to columns is not stable in chlorine house in WTP No.5. Since marble veneer has already fallen down, and installation position is high, it is dangerous in case of earthquake. There are two alternatives: one is to strip off all of them and re-install with small anchor bolts, another is to fix them by anchor bolts on veneer. Second method is recommended because it is easy and more secure.

(4) Mechanical and Electrical Equipment

At present, incoming cable is already duplicated at almost all the pump stations, and standby pump is installed at each pump station to minimize the damage effect. So minimization of the damage effect is approximately fulfilled.

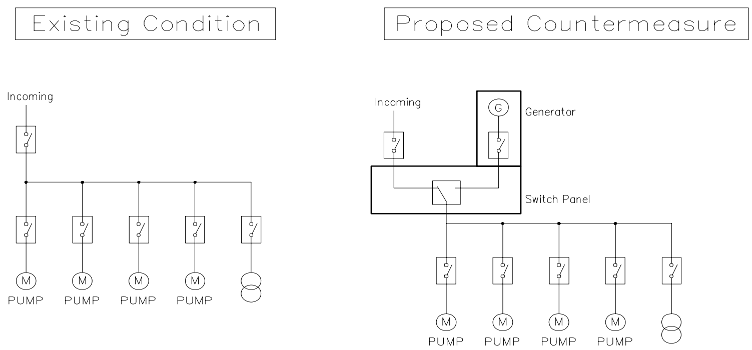
However, emergency generator is not installed at each pump station. When power supply is interrupted, operation of pump has to be stopped. Moreover, safety equipment for chlorine dosing equipment is not installed, and anti-flowout fence for fuel tank is not constructed, that may cause secondary disaster.

So, the Duplication of Power Source on Pump station for securing the reliability of power supply, possibility of Generator's introduction, safety equipment for chlorine dosing equipment and anti-flowout fence for fuel tank have been studied.

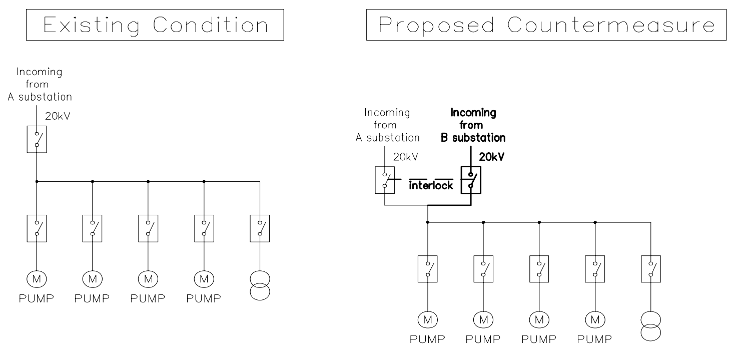
1) Duplication of Power Source

Figure 6.3.21 shows countermeasures for duplicating power source at a typical pump station. a) is a countermeasure by installment of emergency generator, b) is a countermeasure by duplicating incoming cable. a) is a more reliable system but construction cost is very high. (See Appendix).

In addition, Generator for Pump station is actually huge, requires vast area for arrangement, and less working ratio (once a 100-year), also regular maintenance is necessary once a month. Therefore countermeasure a) is considered as not realistic. So in the future when renewal of facility would be coming, installation of Generator ought to be studied.



a. Installation of Emergency Generator



b. Duplication of Incoming Cable

Figure 6.3.21 Countermeasure for Duplicating Power Source at Typical Pumping Station

2) Mitigation of Secondary Disaster

Figure 6.3.22 shows countermeasure plan against oil leakage at WTP No.1. If oil leaks out from the fuel tank by the damage due to earthquake, fuel is stored in the anti-flowout fence, and risk of fire would diminish.

Figure 6.3.23 shows basic flow diagram of on-site generation of sodium hypochlorite system.

In Japan, liquefied chlorine gas was mainly used in 1950's-60's. On the other hand, sodium hypochlorite system began to be adopted in the middle and small scale water supply facilities around 1975. Sodium hypochlorite system also has been adopted in the large scale water supply facilities these days, due to growing number of residence adjoining water supply facilities, technology improvement, and preparation of supply organization aimed at mass consumers.

Figure 6.3.24 shows basic flow diagram of neutralization equipment to diminish gas poisoning. This system is generally composed of a caustic soda storage tank, an absorption tower, a chemical pump, and a blower. The blower draws contaminated air by chlorine gas through a suction duct from the house, and conveys the gas to the absorption tower. While the caustic soda pump supplies caustic soda solution to the upper part of the absorption tower, the resultant neutral gas will be discharged into the air.

In addition to neutralization equipment, gas shutoff valve is also effective to prevent secondary disasters.

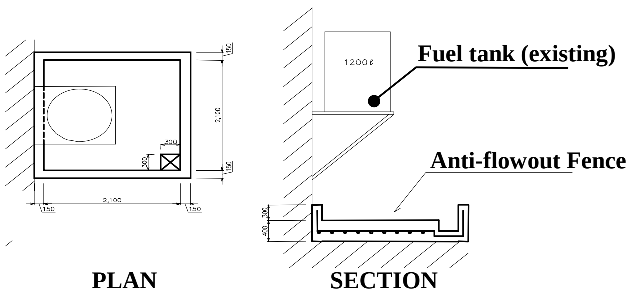


Figure 6.3.22 Anti-flowout Fence at WTP No.1

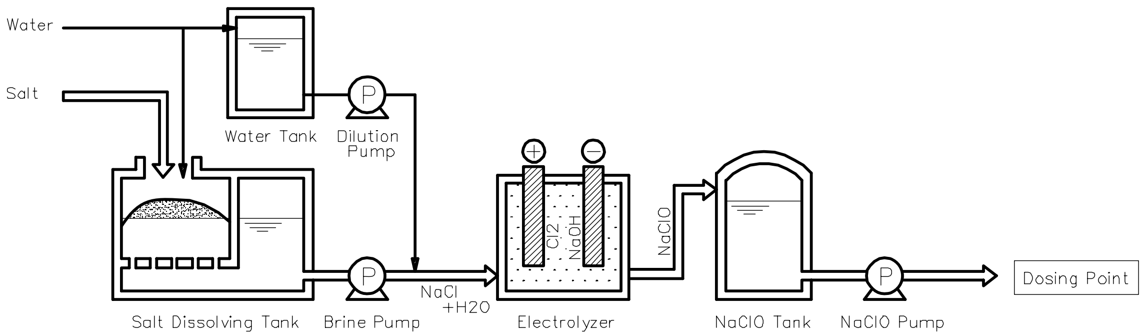


Figure 6.3.23 Basic Flow Diagram of On-site Generation of Sodium Hypochlorite System

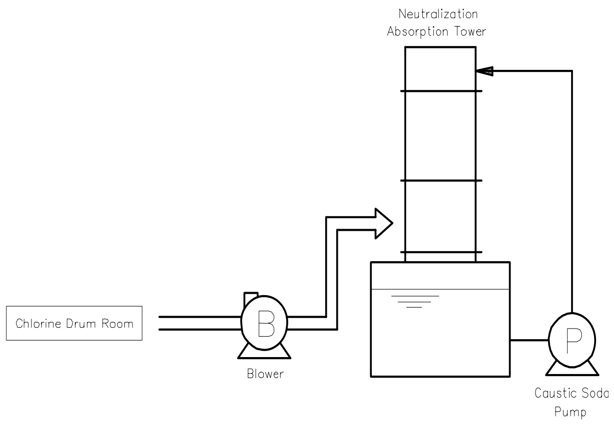


Figure 6.3.24 Flow Diagram of Neutralization Equipment

6.3.4 Look-over the Proposed Countermeasures in Terms of Risk Control

The previously proposed countermeasure should be confirmed on Inventory of Risk& Countermeasures (*Table 6.3.5*) in terms of response to the possible risks that consist of experience in Japan and Iranian concerns based on Brainstorming. This process must be carried out to keep away an error on oversight of countermeasures.

Table 6.3.5 has a function of a Checklist to make the previously proposed earthquake-resistant measures checked in this table regarding the following;

- Proposed measures are categorized as feasible Implementation Plan and ideal Future Plan.
- Pending issue required further survey is confirmed based on the reason of pending, such as stabilization of slope, described the reason of requiring geological survey in a table.
- Non-application measures are confirmed.

If there is an oversight on measures, study would be fed back to site survey, DTSC and selection of target facilities as described in previous section 4, and countermeasure would be studied again. In this study, possible countermeasures are checked based on the present conditions.

Table 6.3.5 Risk Control Chart (check sheet of measures)

I	Implementation Plan
F	Future plan
P	Pending issue “Reason of Pending”
N	Non-application (general countermeasure)

Risk		Check of the Countermeasures
S-1 Risk on Ground conditions		
S-1-1-1 Fault shifts causes great damage to structures and subsequently accidents resulting in injury or death	**F**	S-1-1-1-a Replacement (shifting of location and re-construction)： (Reservoir No. 11, 14, 20, 26, 75, 77, 82, Chlorine house, chemical house and Pulsator at WTP No. 5, Pulsator and Filter at WTP No. 4, Reservoir at WTP No. 3&4(No. 71, 95, 97) Construction finance is not involved in Earthquake-resistant plan.
	I	S-1-1-1-b Back up by other function Reservoir No. 11, 14, 20, 26, 75, 77, 82, Chlorine house, chemical house and Pulsator at WTP No. 5, Pulsator and Filter at WTP No. 4, Reservoir No. 71, 95, 97 at WTP No. 3&4
S-1-1-2 A soft-ground soil slides and differential settlement occurs and the structure inclines, or crack in concrete leads to water leakage	**P**	S-1-1-2-a Ground-improvement method S-1-1-2-b Piling or sheeting for ground transfer prevention “Required geological survey of slope at Reservoir No. 68, 89”
S-1-1-3 Liquefaction occurs and differential settlement occurs and structure inclines, or crack of concrete causes water leakage	**N**	S-1-1-3-a Ground-improvement method S-1-1-3-b Ground-water fall method S-1-1-3-c Ground-water interception sheeting

S-1-1-4 A cliff collapses and damages the building.	P	S-1-1-4-a Falling-stone prevention wall, Retaining Wall S-1-1-4-b Concrete spraying on slope S-1-1-4-c A forestation on slope S-1-1-4-d Ground anchor retaining on cliff S-1-1-4-e Ground-improvement method on slop/cliff "Required geological survey at Reservoir No.26, 28, and Bileghan Intake"
	I	S-1-1-4-f Construction of defensive wall on building Bileghan Shelter
S-1-1- Landfill collapses or exposed foundation causes differential settlement.	N	S-1-1-5-a Ground-improvement method S-1-1-5-b Slope stability method (S-1-1-4-b, S-1-1-4-c)
S-1-1-6 A slope collapses and damages the facilities, private residence, or road	P	S-1-1-6-a Ground-improvement method "Required geological survey of southern premises of Reservoir No.55 and eastern premises of Reservoir No.25 for private residence" S-1-1-6-b Slope stability method (S-1-1-4-b, S-1-1-4-c) "Required geological survey at Reservoir No.38 for road, No.23 and No. 91 for telemetry building placed by the slope"
S-2 Risk on Structural members		
S-2-1-1 Column collapses, and beam and roof deform or fall.		S-2-1-1-a Frame reinforcement by steel brace
	I	S-2-1-1-b Frame reinforcement by RC shear wall Generator house at WTP No.1, Generator house at WTP No.2, Pumping houses No.1, 2, 15, 16, 17, 19, 20, 22, 24, 36,40, 52, 57, 58, 73, 27, 28, 38
		S-2-1-1-c Reinforcement by carbon fiber sheet
	N	S-2-1-1-d Cross-sectional partial reinforcement by steel plate
S-2-1-2 Crack occurs at the tank, causes water leakage and water is contaminated.	I	S-2-1-2-a Reinforcement of partial member Pulsator on WTP No.2 Oldest Reservoir No.1, 2, 3, 4, 5, 6 Old Reservoir No.9, 10, 11, 13, 15, 16, 20, 23, 25, 29, 30, 32 (These are target facilities, but further soil survey is required)
	F	S-2-1-2-a Reinforcement of partial member (relatively new) Reservoir No.24, 27, 28, 33, 37, 38, 40, 41, 51, 53, 57, 58, 63, 72 "further soil survey is required."
		S-2-1-2-b Installation of slab and transmits horizontal force to wall
S-2-1-3 When whole structure deforms, a deformation becomes the maximum by Expansion Joint, so water stop is cut and water leaks.	N	S-2-1-3-a Addition of water-stop
	I	S-2-1-3-b Abolishment of the effectiveness of Expansion Joint and unification of a part of structure Filer at WTP No.4
S-2-2-1 As the structure is complicated,		S-2-2-1-a Ground-improvement method

when structural model is not optimal, the inestimable force acts, which causes the increase of load on some members, and deformation.	I	S-2-2-1-b Fixation of Breezeway WTP No.4 chemical house
		S-2-2-1-c Support of cantilever structure
S-2-2-2 If the foundation is bad toppling of Over Head Reservoir causes a second disaster on the outskirts.	P	S-2-2-2-a Ground-improvement method S-2-2-2-b Extension of foundation width "Required geological survey of elevated tank's foundation at Reservoir at No.68"
S-2-3-1 When there is large degradation which the bar has exposed, as the structural function is lost and earthquake resistance cannot be expected, buckling, deformation, crack, leakage of water, etc. occur.	I	S-2-3-1-a Repair (Refurbishment) Reservoir No.6, 66
S-3 Risk on Non-structural members		
S-3-1-1 The trough of Pulsator gets separated or breaks down and water quality deteriorates.	F	S-3-1-1-a Extension of support bearing length
	I	S-3-1-1-b Stopper Pulsator's trough in WTP No.2 is reinforced together with the wall
S-3-2-1 The brick wall collapses and causes an accident resulting in injury or death, or equipment is damaged.	I	S-3-2-1-a Reinforcement of brick wall Building of WTP, Pump House and Emergency Post
	N	S-3-2-1-b Replacement with an alternate light material
S-3-3-1 Windowpane breaks because of caulking material degradation which can cause an accident resulting in injury or death.	I	S-3-3-1-a Replacement with the degraded window and frame. (common countermeasure)
		S-3-3-1-b Shatter-resistant film should be pasted on windowpane (common countermeasure)
S-3-3 –2 Broken door prevents a man to escape	I	S-3-3 - 2-a Replacement with the degraded door and frame. (common countermeasure)
S-3-4-1 The outer Marble Veneer falls, which causes an accident resulting in injury or death.	I	S-3-4 -1-a Fixation with anchor bolt The outer Marble Veneer of chlorine house of WTP No.5
	N	S-3-4 -1-b Re-work
S-3-5-1 same as S-2-1-3	N	S-3-5-1-a Installation of a water stop with big displacement
S-3-6-1 A Retaining Wall topples and a building slides, and this causes an accident resulting in injury or death.	P	S-3-6-1-a Backfilling-improvement S-3-6-1-b Foundation Soil-improvement S-3-6-1-c Fixation with Earth anchor S-3-6-1-d Fixation with Tieback pile "Required geological survey of Retaining wall of chemical house at WTP No.5"
S-3-7-1 A man may fall over handrail resulting in injury or death.	I	S-2-7-1-a Fixation of handrail post (common countermeasure)
	I	S-2-7-1-b Replacement of the high handrail (common countermeasure)
E-1 Risk on Main Equipments		
E-1-1-1 Overturn of surge tank leads to failure of pumping.	I	E-1-1-1-a Fixation with foundation bolt
	I	E-1-1-1-b Installation of additional support Pump station No.2, 22, 96

E-1-1-2 Gas leakage from chlorine cylinder causes an accident resulting in injury or death.	I	E-1-1-2-a Installation of stable pedestal Bileghan, WTP No.1 to No.3, and Stations No. 1, 2, 13, 14, 15, 16, 17, 19, 20, 21, 22, 24, 25, 26, 40, 52, 56, 57, 58, 65, 68, 73, 114
	I	E-1-1-2-b Installation of neutralization equipment and emergency shutoff valve Bileghan Intake, WTP No.1 to 5, Stations No.52, 73, 4, 5, 7, 13, 19, 21, 31, 36, 40, 65, 66, 68, 69, 89, Southern Tarasht, Said Abad
	F	E-1-1-2-c Replacement of the chlorine dosing system with safer systems such as sodium hypo chlorite system.
	N	E-1-1-2-d Re-piping copper chlorine tube with enough spare length
	N	E-1-1-2-e Reinforcement the brick wall to the RC wall which the copper chlorine tube pass through. (belong to non-sructure member)
E-1-1-3 Overturn or sideslip of transformer causes failure of the water supply and fire.	I	E-1-1-3-a Fixation with foundation bolt in addition to stopper All transformers
E-1-1-4 Overturn of electrical panel causes operating failure of the water supply.	I	E-1-1-4-a Fixation with foundation bolt pump station No.8, 12, 13, 27, 28, 32, 34, 36, 37, 38, 43, 59, 65, 66, 68, 69, 71, 72, 74, 75, 80, 81, 90, 91, 93, 95, 96, 101, 102, 105, Well Pump
	I	E-1-1-4-b Reinforcing of stage Reinforcement of steel stage at Pump station No.72, would include the countermeasure of fixation of panel.
E-1-1-5 Overturn of pump causes operating failure of the water supply.	N	E-1-1-5-a Fixation with foundation bolt E-1-1-5-b Installation of stand by Pump
E-1-2-1 Damage to pipe causes leakage of water, failure of water supply, and failure of emergency water supply.	I	E-1-2-1-a Installation of flexible pipe WTP No.1 to No.5, Bileghan Intake
	I	E-1-2-1-b Installation of emergency shut-off valve at outlet of reservoir All Reservoir (Section 6.1)
E-1-2-2 Damage to cable causes operating failure of the water supply.	N	E-1-2-2-a Rewiring of cable for the important equipment with enough spare length.
E-1-2-3 Leakage of fuel for emergency generator causes secondary disaster like fire	I	E-1-2-3-a Construction of anti-flowout fence Generator in Bileghan Intake GeneratorWTP No.1 to No.5
E-1-2-4 Toppling of electric post causes power failure.	I	E-1-2-4-a Installation of stay. Reservoir No.22
E-1-2-5 A man between huge piping couldn't escape and falls a victim in the pump room.	N	E-1-2-5-a Installation of stages over piping
E-1-3-1 (Blackout) Failure of water supply, or deterioration of water quality	F	E-1-3-1-a Installation of emergency generator
	I	E-1-3-1-b Duplicate Incoming Cable Pump Station No.16, 52, 68, 114
E-1-4-1 (Reliability of equipment) Equipment breaks down and does not	N	E-1-4-1-a replacement

work or a glitch occurs.		
E-1-5-1 (Information) As broadcast does not inform the earthquake intensity for every area, workers couldn't concentrate on emergency work due to being anxious about their family's safety.	**P**	E-1-5-1-1 Allocation of the seismometer in the telemetry building, and offer the earthquake information to the broadcasting station. "TWWC itself has to study"
E-1-5-2 (Information) As the whole damage cannot be grasped, suitable directions cannot be taken from the disaster countermeasures headquarters. No idea of the action for workers. Before directions come from headquarters, workers might go home.	**P**	E-1-5-2-1 Giving the commitment to telemetry staff of the damage report situation of reservoir, pump station, surrounding buildings and road to the disaster countermeasures. "TWWC itself has to study"
	P	E-1-5-2-2 Creation of an action manual in case of an earthquake "Required advancement of organization"
E-2 Risk on Sub Equipments		
E-2-1-1 Overturn or sideslip of battery causes failure in operation of radio equipment, monitoring equipment, display lamp of electrical panel , and operation of circuit breaker	**I**	E-2-1-1-a Fixation with foundation bolt WTP No.1 to No.5 Pump Stations No.1, 2, 13, 14, 15, 16, 17, 19, 20, 21, 22, 24, 25, 26, 40, 52, 56, 57, 58, 65, 68, 73, 114
E-2-2-1 Overturn of UPS causes operating failure of monitoring equipment until emergency generator starts when blackout takes place.	**I**	E-2-2-1-a Fixation with foundation bolt WTP No.1 to No.5
P-1 Risk on Connecting piping		
P-1-1-1 Piping gets separated from the tank which leads to water leakage, so emergency water supply becomes impossible.	**I**	P-1-1-1-a Installation of flexible joint (at least one line) Section 6.2
	I	P-1-1-1-b Installation of back-up pipe with flexible joint Section 6.2
P-1-1-2 Valve is not working which causes water leakage or failure of the water supply.	**P**	P-1-1-2-a Replacement of the valve with flexible joint "Required detail site survey by maintainer".
P-1-1-3 person well versed of the piping system in the headquarters is absent, and instructions of valve operation cannot be executed.	**P**	P-1-1-3-a Development of GIS "Required further study focus on GIS"
	P	P-1-1-3-b Grasp of the water-supply area by the maintainer "TWWC itself has to study."

6.3.5 Check of Task

Previously Study Team confirmed the tasks of Seismic Diagnosis and Earthquake-Resistant plan through WBS (Work Breakdown Structure), and Work Package was set up. WBS itself becomes Checklist of task. So using WBS, items of all work packages of diagnostic tasks on Facilities and Equipment would be checked/overlooked to ascertain the accuracy of the study, or summarize the findings wherever possible so far. All work packages were confirmed on *Table 6.3.6*, that would be obtained through Seismic Diagnosis to Earthquake-Resistant Plan.

Table 6.3.6 Checklist of Work Package

Category Ⅰ	Category Ⅱ	Work Package	Finding /Checking
Confirmation of common matter	Arrangement of general matter	Confirmation of design year and construction year	Design date is not available. But operation date is known on almost all facilities. In some cases operation is started after construction years.
	Importance and ambient environment of facilities	Selection of the matter with regard to the importance of facilities	It is classified according to the ease of emergency repair, supply capacity, facility located in the upstream of system, information headquarters such as disaster countermeasures office, and etc. Refer to importance of classification *Table 4.2.2* .
		Environment condition and geographical features of the site surroundings	See Appendix DTSC
		Historical record of land	It is considered that the facility is built at the vacant lot.
	Checking of the past disaster	The date of occurrence, a disaster situation, the details on repair carried out	There is no big earthquake. There was no remarkable damages, only one damaged case of asbestos pipe in WTP No.3
	The situation of maintenance	Visual investigation of function	Maintenance is generally good. Because there are a maintainer even on small Reservoir.
	Earthquake resistance of water supply system	Availability of network planning	The project of the network of Distribution is under enforcement.
		Availability of alternative channel or alternative facility	1.Alternative channels and alternative transmission mains do not exist. 2.There are five WTPs, and these have duplicate treatment tanks. 3.There are many Pump Stations and Reservoirs. Reservoirs have duplicate compartments. 4. Distribution pipe is complemented mutually.
Diagnosis of Ground condition	Collection and Compilation of data	Geographical feature data	Electronic data are available.
		Soil investigation data	1.It is available on the basis of earthquake motion analysis general/rough data. 2.On the whole, ground is firm. On the construction site of Telemetry house, the depth of foundation is set to 2m where good soil comes out.
		Availability of insufficient data	Though the soil data behind the wall of Reservoirs/tanks were required for structural analysis, acquisition of new ground data was difficult.
	Soil values	Sorting out of soil characteristic values	Rough N-value is available on the basis of earthquake motion analysis data.
	Sorting out of ground analysis	Liquefaction	1.It is available on the basis of earthquake motion analysis data. 2.The ground water level is below facilities (Pipe, Reservoir, WTP), ground is good because of variety of granulometry/ particle size distribution, and there is no broad fine sand layer, so it is judged that there will be no liquefaction in the ground of target facilities.
		Consolidation calculation	It is said there is consolidation layer, but not on the object facilities. Data was not available.
	Visual investigation	Investigation of excavation work	It was observed that, as the ground condition was good, excavation was carried out

			vertically at the construction field of telemetry house, the extension field of Reservoir, and so on.
		Investigation of differential settlement	Some small differential settlements were confirmed on west foundation of pump house No.74 and the backfilling of retaining wall at WTP No.5.
	Review of results of investigation	Reduction of soil characteristic value on account of liquefaction	No need.
		Calculation of the amount of cavities which sank	No need.
		Study of ground lateral shift probability in relation to liquefaction	Ground condition is good and the ground water level is low, so there is neither liquefaction nor lateral movement of ground in a theoretical sense. But soil investigation should be done on Reservoir No.55, as concerned with other incidental affairs.
Earthquake Resistance of Structure	Collection and compilation of data	Collection and sorting out of As-built drawing and design calculation	Since the original as-built drawing is kept at Archive room, if it applies for the facility name, it serves as a system which the person in charge of Archive room has arranged. But many drawing especially bar arrangement drawings are lost.
		Availability of insufficient data	It's difficult to collect.
	Visual investigation	The situations of arrangement of buildings on premise.	There is sufficient space for emergency repair except for No.14, 20, 104, 105, and Tarasht PS in the investigated facilities.
		The settlement situation of building	It was slightly observed on Pump House of Reservoir No.74.
		The degradation situation of structure, set up of the reduction coefficient of material strength	As a result site survey degradation is not advanced except for Reservoir of No.6, No.66. and Filter on WTP No.4. Coefficient of material strength should be reduced. But old concrete observed is very good. so design strength might be secured.
		Location and specification of Expansion Joint.	The location was checked. As for the specification it is a simple plate made from vinyl chloride or copper plate.
	Confirmation of original design condition	Design year	Unknown
		The list of design-criteria at the time of design	Unknown, since the statement does not remain
		Ground condition	Unknown, since no relevant statement exists
		The situation of pile	Although it was not clarified in a hearing, pile might have not been adopted judging from a good ground condition. If there was structure with pile, it could be applied for the tall structure. That kind of building is not included in the object facility.
		Conditions of Foundation calculation	Unknown but, since the foundation is good, bearing capacity might be sufficient.
	Qualitative earthquake resistance evaluation	Existence of seismic design	The design of WTP No.5 and so on. We assumed that the design after 1995 would be adopted according to seismic design and made seismic diagnosis.
		Seismic-design criteria considered at the time of design	Code of Practice (Standard 2800)
		Existence of load increase	Now at the existing Reservoir, landscaping project is performed only as walkway and gravel pavement. There is consideration of no increase of load. Therefore, there is no risk of damages dependent on the increase of load in the future.

	Condition of Pile crown	Unknown
Evaluation of the existing data	Evaluation of existing structural calculation	Structural calculation documents of new structures designed by code 2800 existe. As a result of evaluation, since those structures such as Telemetry Buildings are designed strictly based on the cord, seismic resistance is sufficient.
	The review of the existing diagnostic data	As a result of reviewing diagnosis of facilities in "Earthquake-resistant diagnosis/TWWC", the contents should be involved in the diagnosis of the study.
Evaluation By simple calculation	Calculation and evaluation of shear wall	Wall is brick wall, which cannot be evaluated as earthquake resistant measure on the simple calculation method used in Japan.
Evaluation by Detailed seismic diagnosis	The necessity for detailed diagnosis	Since situations of facilities differ variously, it can be diagnosed neither by the design year nor the type of structure. Therefore, an individual detailed diagnosis is required case by case.
	Physical test	In consequence of the physical test, neutralization is not advancing, it is concluded that advance of neutralization is slow in Tehran because of dry climate and the high construction technology/workmanship of concreting. As a result of the non-destructive test by a Schmidt rebound hammer, it was confirmed the compressive strength of several concretes are very high.
	Structural analysis	The structural analysis of several models was carried out and the Seismic resistance confirmed as follows. 1. Underground oldest structure (Reservoir No.6, age 1955) is slightly fragile. 2. On the other hand, one of relatively new reservoir (Reservoir No.23, age 1970) has high seismic resistance. 3. Long beam one storey Structure above ground (Generator House of WTP No.1) is very fragile, has not seismic resistance. 4. Seismic resistance of Pumping house (Reservoir No.2) is middle. 5. Filter on WTP has high seismic resistance. 6. Pulsator only on WTP No.2 is slightly fragile. As we look over the tendency, tank of wall structure has high seismic resistance, but big building has no seismic resistance.
	Earthquake resistance evaluation of joint piping or connecting pipes with tank	As the ground condition is so firm, there is little displacement, seismic resistance is high. But it is better to take flexible joint into consideration for safety.
	Assessment of damage	Evaluations of four scenario earthquakes on the major damage risk factors of facility were performed on the basis of DTSC. Only in the case of North Tehran Fault, damage was observed remarkably, occurrence probability is so rare though.
	Emergency repair plan	This would be carried out in consequent section.
Study of earthquake -resistant countermeasures	Study of the reinforcement	The countermeasures based on site survey and risk assessment is presented, and reinforcement is proposed.
	Creation of design drawing	See Appendix.

	Preparation of Earthquake-resistant plan	Determination of the priority of construction	Project priority is determined in terms of sustaining human life, importance classification and as well as the damage assessment.
		The confirmation of the annual budget of TWWC	The budget on earthquake-resistant plan could not be confirmed.
		Rough estimation of construction cost	See section 7
		The construction plan proposed	See section 7
		The structural detail for seismic design proposed	See Appendix
Earthquake resistant for Non-Structural Member	Visual investigation	Confirmation of fixed situations, such as finishing material and handrail	It was inspected.
	Study of countermeasure	Study of the reinforcement	Fixation of brick wall, outer marble veneer, etc. was proposed.
	Preparation of Earthquake-resistant plan	Calculation of approximate construction cost	See section 7
		The construction plan proposed	See section 7
		The structural detail for seismic design proposed	See Appendix
Earthquake resistant for Mechanical and Electrical Equipment	Collection and sorting out of data	Collection and sorting out of As-built drawing	Required data were collected.
		Collection and sorting out of structural calculation for foundation-bolt	There is no statement of structural calculation of foundation-bolt.
		Confirmation of alternative equipment	TWWC finished checking the existence of backup of pump in all stations by our request.
	Visual investigation	Installation situation of pumps	The installation situation is good.
		Installation situation of surge tanks	Although the installation situation is good., earthquake resistance is not determined by visual investigation. By serious seismic diagnostic calculations, the risk of a toppling and a sideslip is checked. Since the middle support of the surge tank is not installed at Pump station No.2, No.22, No.96, they may be insufficient for earthquake resistance. There is a big crack in the foundation of No.22 and it should be repaired immediately.
		Chlorine dosing equipments	Except for WTP No.5, the cylinder is not being fixed firmly. It's suspected as the cause of a secondary disaster. Moreover, there is no neutralization equipment.
		Existence of Emergency shut-off valve	There are no emergency shut-off valves.
		Installation situation of Self-standing panel	Visually, the fixed situation of metallic attachments cannot be checked. Panels are categorized as three types of Type A, Type B and Type C.
		Installation situation of Battery	The battery is not being fixed with a bolt. There is a danger of toppling and sideslip.
		Installation situation of UPS	The UPS is not being fixed with a bolt. There is a danger of toppling and sideslip.
		Installation situation of Flexible pipe	Except for WTP No.5, the flexible pipe is not installed in the location of expansion-joint.
		Sufficient or insufficient length of spare cable	Spare cable is not secured. Re-laying of the cable is highly required.
		Existence of Emergency generator	There is no emergency power source in a pump station.
		Existence of Anti-flowout fence under the oil tank	There is no anti-flowout fence beneath the oil tank on a generator. It's suspected as a cause of a secondary disaster.

		Installation situation of Electric post	Stay is not installed. There is a danger of toppling.
	Evaluations by detailed diagnosis	The necessity for detailed diagnosis	It should be studied as an essential part in detailed diagnosis, so far carried out.
		Calculation of toppling and sideslip risk	Strength calculation of the foundation bolt was performed. *The risk of a toppling and a sideslip of pump is small *Since in-between support of the surge tank at Pump station No.2, No.22, No.96, was not installed, it was insufficient for earthquake resistance. *The earthquake resistance of great amount of Self-standing panel was high.
	earthquake-resistant countermeasure	Study of the reinforcement	It' is carried out on the basis of above evaluations.
		The outline of proposed design	See main text and Appendix.
	Preparation of Earthquake-resistant plan	Calculation of approximate construction cost	See section 7, and Appendix.
		The construction plan proposed	See section 7
		The seismic design guide line proposed	Manual for Seismic Diagnosis is submitted; the fixation's analysis method was proposed on this.

6.4 Facilities and Measures for Emergency Water Supply Bases

This section focuses on:

- How emergency water supply method is selected, and
- How water supply base is allocated

Other measures with respect to emergency water supply and emergency restoration are explained in the following "Chapter 8".

6.4.1 Selection of Emergency Water Supply Method

Emergency water supply bases should be allocated so that anybody can access within 1 km distance after the earthquake. Existing facilities should be used as much as possible, in order to save initial and total investment for preparation of emergency water supply bases. Therefore following places can be listed up for emergency water supply bases:

- Existing reservoirs
- Existing transmission pipes connected to existing reservoir
- Existing deep wells

For emergency supply use, water in existing reservoir and transmission pipe has following advantages compared to that of deep well:

- Water reserved in existing reservoir and transmission pipe is finished water therefore quality is relatively better than that of well.
- Emergency supply from reservoir does not require large-scale pump or generator.

Therefore supply from existing reservoir is given first priority in selection of supply method. Deep well is considered for the area which cannot be covered by the existing reservoirs, as long as water quality is acceptable. Water tanker and emergency water tank will make up for the above measures.

Above listed measures can be further divided according to their practical application. Following measures are selected for emergency water supply methods after the earthquake disaster in the Study Area:

- Supply from existing reservoir with the arrangement of siphon at outlet pipe
- Supply from existing reservoir with the installation of emergency shut-off valve
- Supply from gravity transmission main of Enqelab and Southern Ring Main
- Supply from deep well owned by TWWC and/or in park
- Supply by water tanker to make up for uncovered area by the existing reservoirs or wells
- Supply by emergency water tank to make up for:
    - area which cannot be accessed by water tanker
    - some wells where water quality is poor for drinking purpose

Each method to be applied for emergency water supply is outlined in the following (1) to (6).

(1) Supply from Existing Reservoir with the Modification of Outlet

1) General

Table 6.4.1 outlines general feature of reservoirs to be used as emergency water supply bases. On the whole, capacity of reservoirs in the Study Area is so designed as to keep equivalent volume, which can accommodate as much as 24 hours in daily maximum basis. Therefore the reservoirs can be considered to reserve enough water for emergency use in terms of capacity, in principle. However, without any countermeasure, water will flow out and cannot be used for emergency water supply base, due to major leakage after the earthquake. In order to prevent accidental massive outflow from reservoirs, installation of emergency shut-off valve is usually considered. However, there are some constraints in installation of emergency shut-off valve:

- Emergency shut-off valve is very expensive
- Flow-sensor type is not available in local market (only differential pressure type, which is not ideal in terms of maintenance, etc.)
- Large diameter valve is not available in local market.

Modification of outlet pipe by means of siphon with the air valve can be substitute for the function of emergency shut-off valve. By this arrangement, one third of total capacity will be kept in case of emergency. In order to save cost, this method will be used as much as possible, as long as there is enough space for installation of chamber for siphon arrangement.

2) Required Preparation for Emergency Use

Following items should be prepared for emergency supply:

- Pipe arrangement for siphon chamber (refer to *Figure 6.4.1*)
- Engine pump with at least 10 m of total head and 0.25 m^3/min of discharge
- At least 3 temporary taps, with 6 outlets for each.
- Storehouse with the area of approximately 15 m2 to store temporary taps, engine pump & fuel, chemical for disinfection, etc. (refer to *Figure 6.4.2*).

3) Verification of Possibility for Emergency Use

Capacity of each reservoir and water volume to be kept is verified in order to confirm if every reservoir has enough capacity for emergency use with the following basis:

- Average population in the Study Area is set as 156 person/ha (= 15,600 person/km^2). Therefore population in coverage area by 1 km radius circle is approximately 50,000 person/1 km-radius coverage area, based on "Iran Statistics data 2005".
- 30 % of total population (15,000 person/1 km-radius coverage area) is set as water supply interrupted population at the initial stage after the earthquake, based on simulation study for restoration work, mentioned in "Chapter 8".
- In order to reserve necessary amount of water for 7 days in case of emergency, water should be kept at least approximately 315 m^3 (= 3 L/d/capita x 7 d x 15,000 person) to reserve water for drinking purpose. About 1,300 m^3 {= (3 L/d/capita x 3 d + 20 L/d/capita x 4 d) x 15,000 person} is needed to cover minimum daily use (drinking, toilet, face washing).
- Therefore, all reservoirs can cover water demand for drinking purpose. Almost all reservoirs have sufficient capacity for minimum daily use. Only reservoirs of No. 018

and No. 096 are below 1,300 m^3 but they can be supplemented by neighboring reservoir namely No. 014 and No. 013 respectively.

Required dimension of siphon chamber is set as following basis:

- Average diameter of outlet pipe of reservoirs is set as 1,000 mm.
- Average depth of reservoirs set as approximately 6 m.
- Therefore, typical dimension of siphon chamber is set so that it can accommodate 1,000 mm diameter of pipes and fittings including air valve, as well as enough space for attaching engine pump in case of emergency (typical one would be approximately W = 6.5 m, L = 6.5 m, H = 7 m).

Required number of temporary tap is set as following basis:

- 30 % of total population (15,000 person/1 km-radius coverage area) is set as water supply interrupted population at the initial stage after the earthquake, based on simulation study for restoration work, as mentioned above.
- For drinking purpose, 45 m^3/d (3 L/d/person x 15,000 person) of water is required.
- Should one family consist of five, 3,000 people will come to take water.
- Given each person use tap for 1 minute, 3,000 minutes is required to complete water supply for 3,000 people.
- Therefore at least 17 taps is required, in order to supply 3,000 people in within 3 hours

4) Particular Note for Emergency Use

- Water shall be pumped up by engine pump.
- Appropriate amount of disinfectant (e.g., calcium hypochlorite) should be applied before supply, if necessary.
- Laminated brief instruction manual for on-site disinfection should be prepared and kept at the site.

Table 6.4.1 Reservoirs to Be Used for Emergency Water Supply

Reservir No.	Capacity (m3)	1/3 of Capacity (m3)	Planning Term	Prevention Measure for Flowout	Reservoir District No. Located at:
No.001	76,600	25,533	S	Siphon Piping	9-61
No.002	76,000	25,333	M&L	Siphon Piping	10
No.003	56,500	18,833	M&L	Siphon Piping	8
No.004	57,500	19,167	M&L	Siphon Piping	1
No.005	57,500	19,167	S	Siphon Piping	2
No.006	57,500	19,167	M&L	Siphon Piping	2
No.007	55,500	18,500	S	Siphon Piping	62
No.008	57,600	19,200	S	Siphon Piping	18
No.010	36,000	12,000	S	Siphon Piping	39
No.011	38,600	12,867	S	Siphon Piping	43
No.012	5,000	1,667	M&L	Siphon Piping	12
No.013	53,500	17,833	S	Siphon Piping	54
No.014	25,000	8,333	S	Siphon Piping	37
No.015	54,500	18,167	M&L	Siphon Piping	13
No.018	2,500	833	M&L	Siphon Piping	37
No.019	20,000	6,667	S	Siphon Piping	40
No.022	37,360	12,453	S	Siphon Piping	38
No.023	32,000	10,667	M&L	E.S.V.	27
No.024	34,600	11,533	S	Siphon Piping	26
No.025	31,200	10,400	M&L	Siphon Piping	27
No.026	52,500	17,500	S	Siphon Piping	28
No.027	12,400	4,133	M&L	Siphon Piping	29
No.028	7,200	2,400	M&L	Siphon Piping	28
No.030	4,000	1,333	M&L	Siphon Piping	32
No.031	37,000	12,333	M&L	E.S.V.	7
No.036	43,700	14,567	S	Siphon Piping	63
No.037	46,000	15,333	S	Siphon Piping	72
No.038	44,712	14,904	M&L	Siphon Piping	82
No.040	15,000	5,000	M&L	E.S.V.	23
No.041	27,000	9,000	S	Siphon Piping	23
No.043	38,000	12,667	S	Siphon Piping	12
No.051	43,000	14,333	S	Siphon Piping	51
No.053	34,000	11,333	S	Siphon Piping	51
No.055	43,200	14,400	S	Siphon Piping	58
No.056	27,300	9,100	S	Siphon Piping	57
No.057	22,800	7,600	M&L	Siphon Piping	58
No.058	20,000	6,667	M&L	Siphon Piping	80
No.059	32,600	10,867	S	Siphon Piping	80
No.063	10,400	3,467	S	Siphon Piping	63
No.065	19,000	6,333	M&L	Siphon Piping	65
No.066	17,250	5,750	S	Siphon Piping	66
No.068	26,400	8,800	S	Siphon Piping	68
No.069	18,500	6,167	S	Siphon Piping	69
No.072	22,700	7,567	S	Siphon Piping	38
No.074	10,560	3,520	S	Siphon Piping	75
No.075	10,700	3,567	M&L	Siphon Piping	77
No.080	25,000	8,333	M&L	Siphon Piping	58
No.081	16,500	5,500	S	Siphon Piping	81
No.082	10,400	3,467	S	Siphon Piping	83
No.089	20,000	6,667	S	Siphon Piping	65
No.096	2,500	833	M&L	Siphon Piping	54

Note:

E.S.V.: *Emergency shut-off valve*
S: *Short-term planning*
M&L: *Medium and long-term planning*

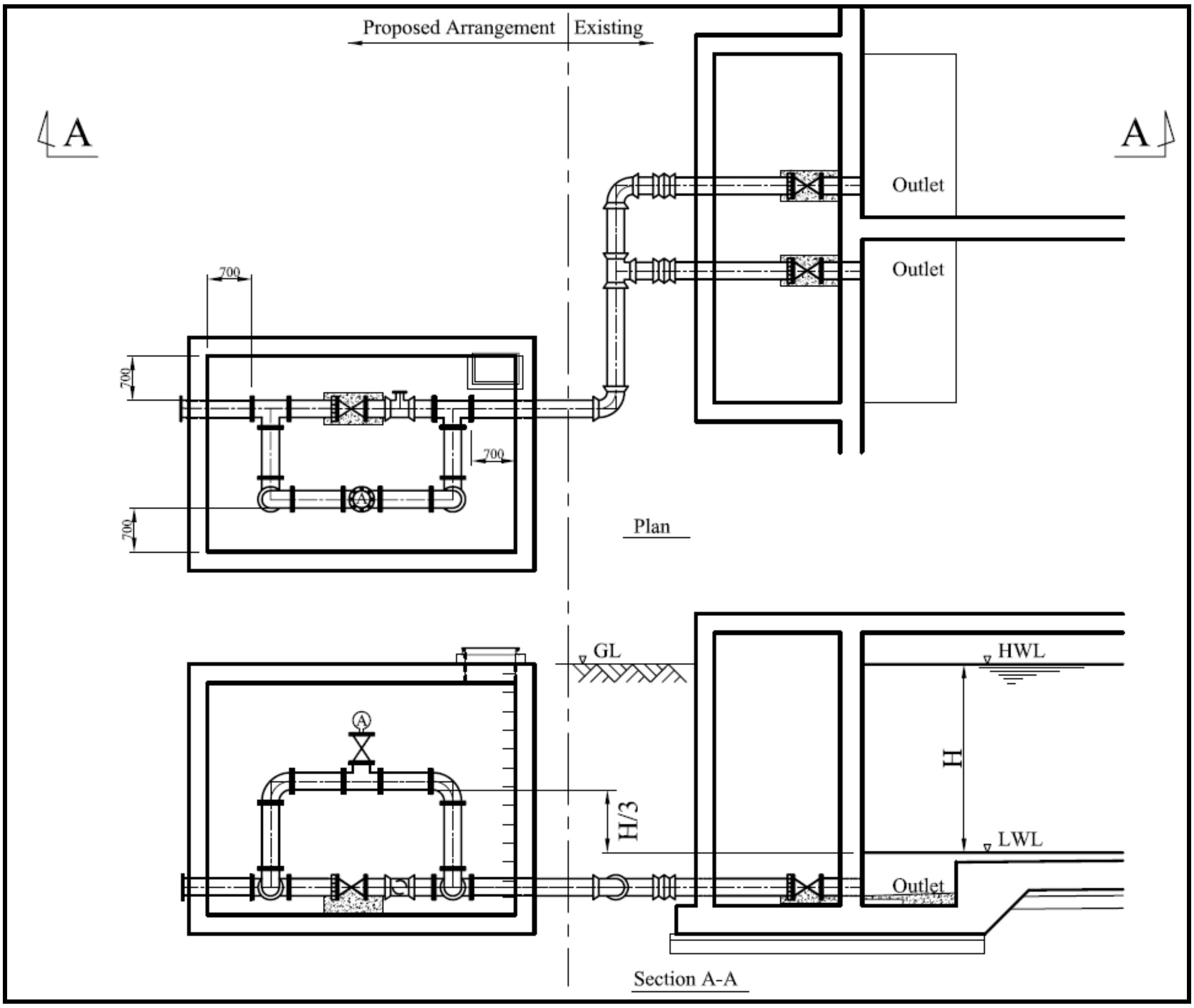


Figure 6.4.1 Example of Siphon Piping Arrangement for Outlet of Existing Reservoir

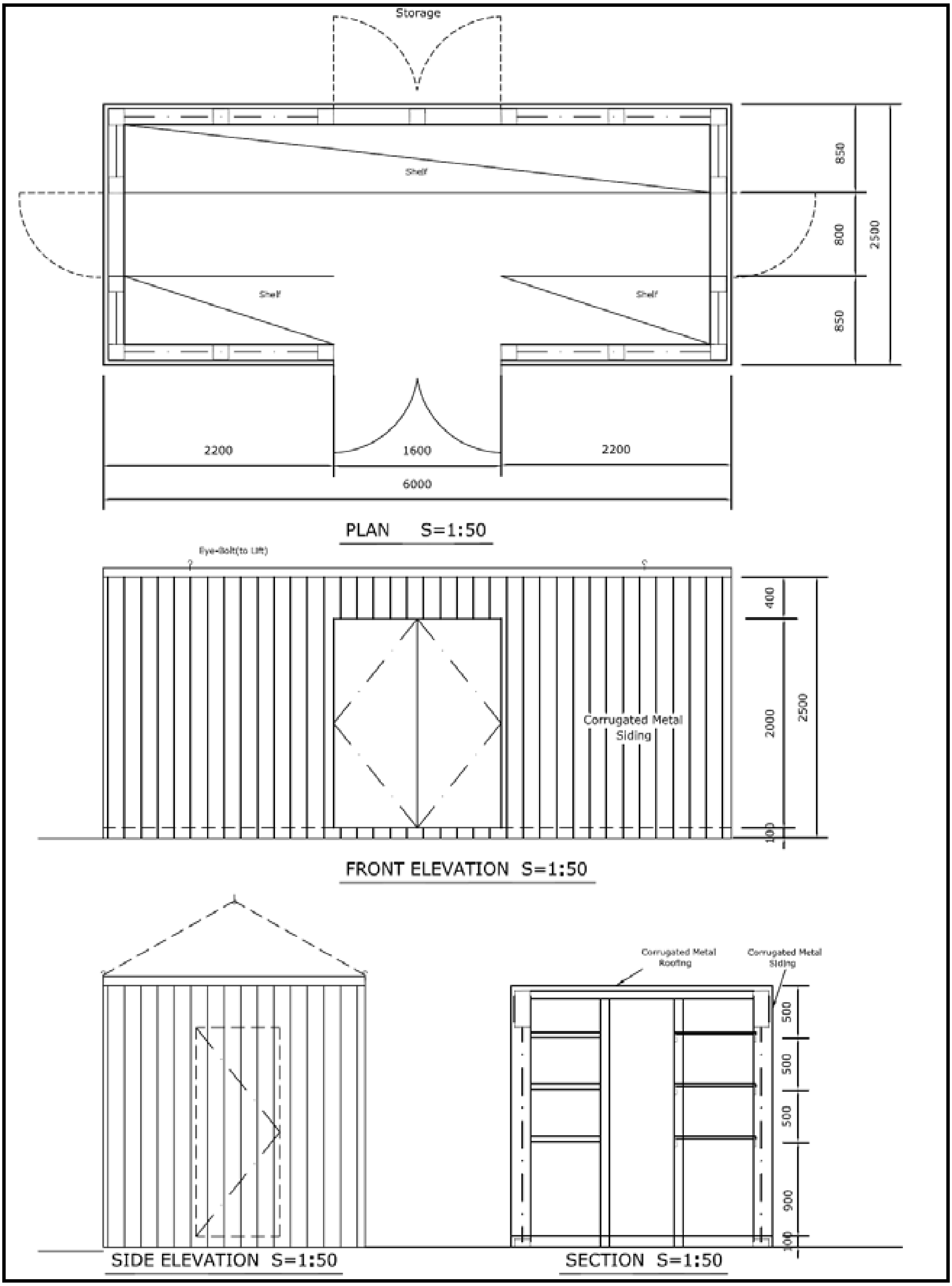


Figure 6.4.2 Example of Storehouse

(2) Supply from Existing Reservoir with the Installation of Emergency Shut-off Valve

1) General

As mentioned above, installation of emergency shut-off valve is one of typical solution to prevent massive flowing out in case of earthquake disaster but it is not feasible to install it in every reservoir due to its high cost. Therefore this valve should be applied only in case there is not enough space for construction of chamber for siphon arrangement.

There are several types of emergency shut-off valve. In this study, mechanical flow-sensor with manual return type, which does not require electricity, is considered (refer to *Figure 6.4.3*)

2) Required Preparation for Emergency Use and Particular Note for Emergency Use

Required preparation and particular note for emergency use are same as (1).

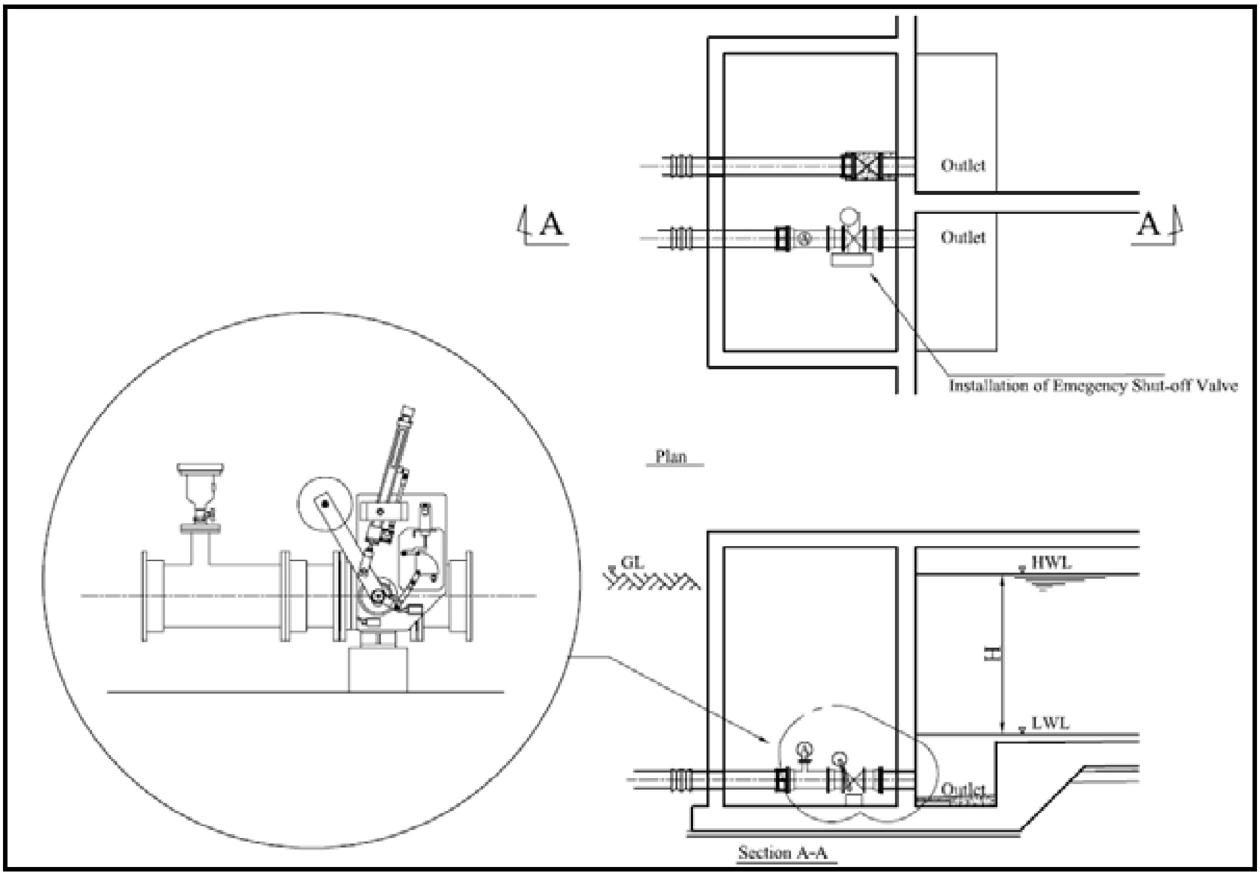


Figure 6.4.3 Example of Installation of Emergency Shut-off Valve to Existing Reservoir

(3) Supply from Gravity Transmission Main of Enqelab and Southern Ring Main

1) General

Concept of this method is similar to the use of existing reservoirs, in principle. At the place where existing reservoir is not available, but located near major transmission pipe namely Enqelab St. & Southern Ring Main, water for emergency use will be provided by these transmission mains (refer to *Figure 6.4.4*).

2) Required Preparation for Emergency Use

Following items should be prepared for emergency supply:

- Transmission pipe shall be branched by invert level tee, for example.
- Fire hydrant shall be installed at the end of the branched pipe.
- At least 3 temporary taps shall be prepared as mentioned in (1).
- 1 storehouse as mentioned in (1) shall be prepared for 2 emergency supply bases and it shall be prepared in nearest park

3) Particular Note for Emergency Use

- Before emergency supply, all valves, which are connected to the transmission pipe for downstream distribution, shall be closed, in order to keep water in the transmission pipe. Function of valves shall be checked at regular intervals.
- Temporary tap will be connected to the fire hydrant to supply water in case of the earthquake.
- Disinfection is regarded to be done at the reservoir which provides water to these transmission mains.

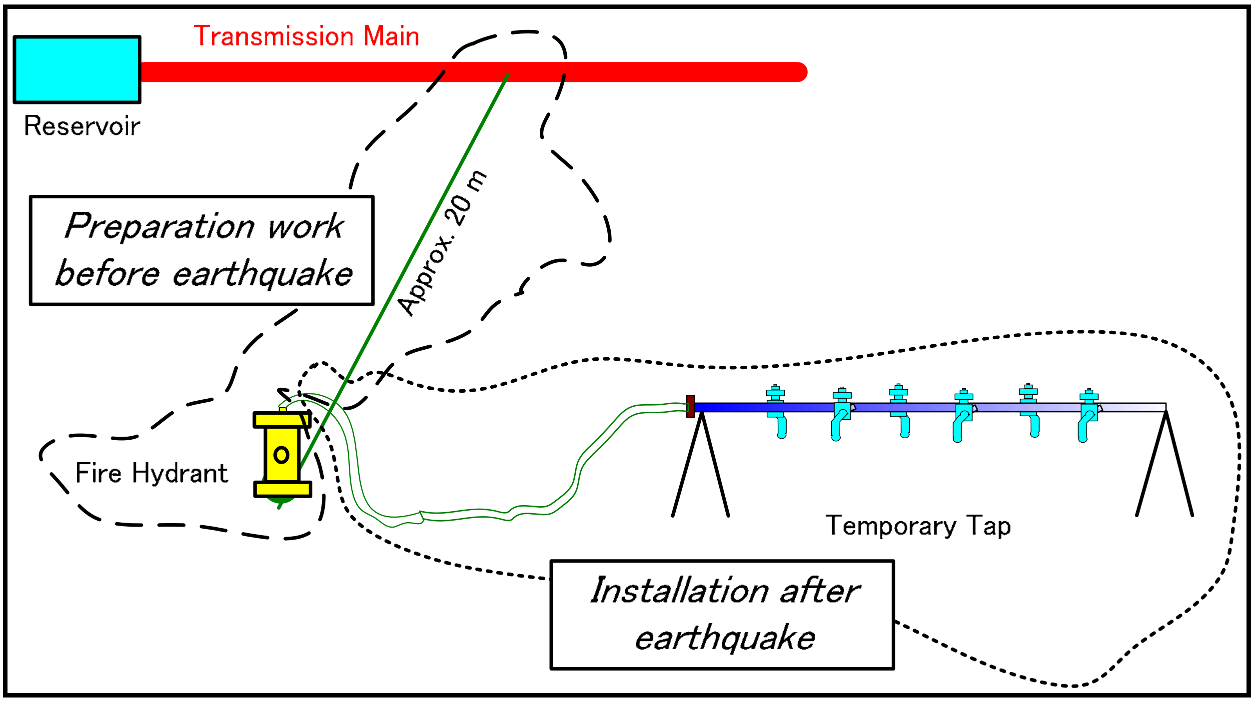


Figure 6.4.4 Schematic Illustration for Branch Connection from Transmission Main

(4) Supply from Deep Well

1) General

Wells will be used where reservoir is not available in and around the objective area.

In case of power failure after the earthquake, power supply for pumping-up to tank, for water reserve and disinfection, will be accommodated by a generator. However, preparation of generator for every well is not feasible in terms of project cost saving. To save cost, minimum necessary number of generators should be prepared. In addition, prepared generators should be stored in decentralized manner and they would be transported to the area where power failure is being prolonged in case of disaster.

2) Special Consideration on Preparation for Generator

Based on the data provided by RTWO, average pump output power of wells in park is estimated as approximately 22 kW. On the other hand, average pump capacity of wells owned by TWWC is estimated as approximately 111 kW. Therefore, to save cost, well in park is firstly considered for emergency supply.

Preparing generator at each well is not feasible in terms of cost. Therefore the number of generators to be prepared is estimated so as to cover the number of wells in southern part of Tehran City, where it would be relatively difficult to be transported by tankers in terms of traffic condition after earthquake disaster.

All generators should be split into 3 to 4 groups to be kept at different places in the city in decentralized manner. In the case of disaster, the deployed generators shall be transported intensively to the part of the city where power failure is prolonged.

Vehicle for transportation of generator shall bring fuel with it. Fuel for diesel oil can be supplied at the service stations in and around the Study Area. Location of service stations, where diesel oil is available and its respective stock volume is presented in *Figure 6.4.5*.

3) Supplemental Installation of Emergency Water Tank

Sufficient numbers of emergency water tank shall be additionally installed in and around the coverage area by some deep wells, especially in southern part of the city where concentration of $N\text{-}NO_3$ is high. Water kept in the emergency tank shall be exclusively used for drinking purpose especially for infants. Feature of emergency water tank is explained in (6).

4) Required Preparation for Emergency Use

Following items should be prepared for emergency supply. Generator shall be separately prepared and transported as mentioned above:

- Transmission pipe shall be branched by such as invert level tee.
- Fire hydrant shall be installed at the end of the branched pipe.
- At least 3 of temporary taps shall be prepared as mentioned in (1).
- Switch board shall be installed so that power can be supplied from generator in case of power failure.
- Storehouse as mentioned in (1) shall be prepared.

In addition to the above, a well in a parks requires a tank with the capacity of approximately 50 m^3. TWWC's wells are regarded to have existing tank, but wells in parks are usually used for sprinkling and does not have tank to reserve water. Therefore tank shall be constructed for wells in parks.

5) Verification of Possibility for Emergency Use

Required dimension of tank is set as following basis:

- 30 % of total population (15,000 person/1 km-radius coverage area) is set as water supply interrupted population at the initial stage after the earthquake as mentioned in (1).
- Therefore 45 m^3/d (3 L/d/person x 15,000 person) of water is required for drinking purpose, as mentioned in (1).
- Example of tank is shown in *Figure 6.4.6*.

Required number of emergency water tanks for supplemental installation is set as following basis:

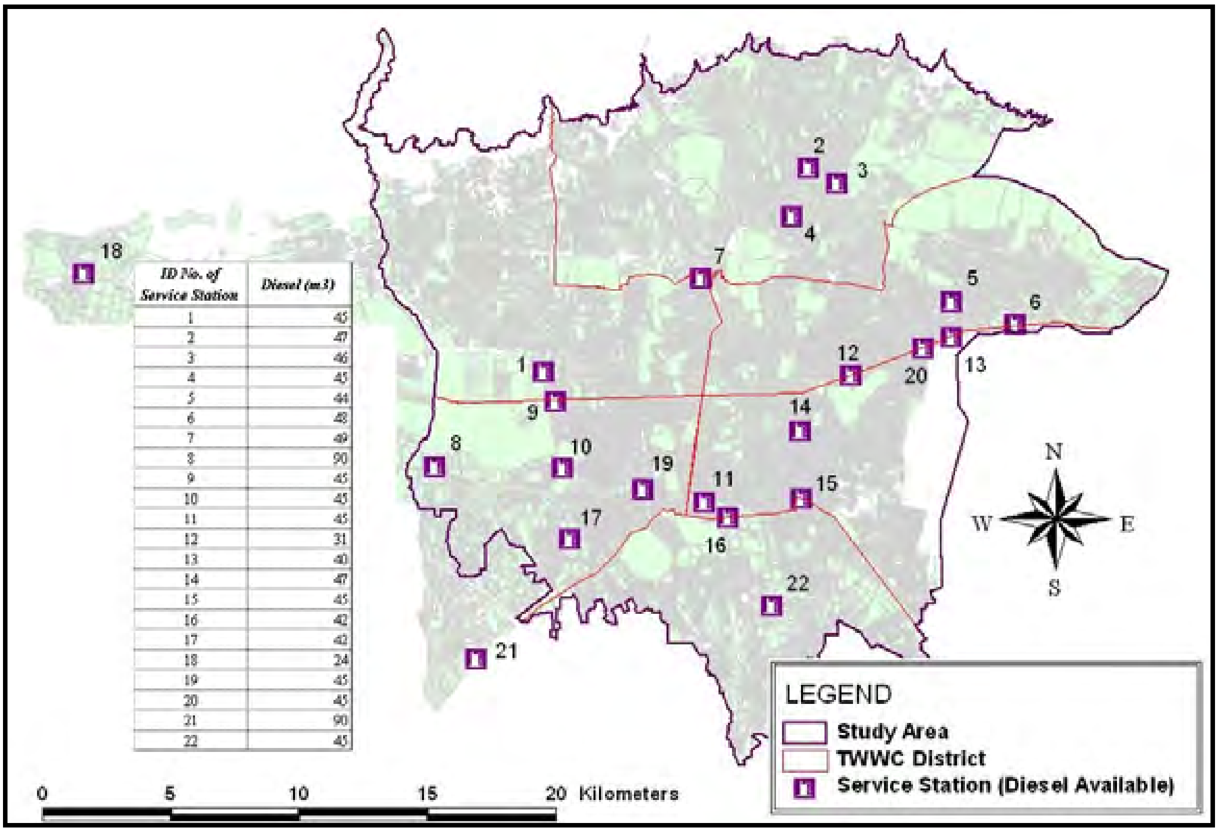
- 30 % of total population (15,000 person/1 km-radius coverage area) is set as water supply interrupted population at the initial stage after the earthquake as mentioned in (1).
- Given 20 % of above is infant, total number of infant is 3,000 people
- In order to supply drinking water for 7 days to 3,000 people, approximately 60 m^3 of water should be reserved in one coverage area.
- Capacity of typical emergency tank is 20 m^3.
- Therefore, at least 3 emergency water tanks shall be installed at the required site.

Water quality of deep well is evaluated as following basis:

- According to the available water quality data of deep well given by TWWC, concentration of toxic heavy metal is under guideline value for drinking water in IRI.
- Therefore, water of deep well is generally fair enough for emergency supply purpose, as long as it is properly disinfected before supply.
- However, in some wells, concentration of $N\text{-}NO_3$ is beyond the guideline value, especially in southern part of Tehran (refer to *Figure 6.4.7*).
- Therefore supplemental measures for securing of drinking water should be taken into account, especially for sensitive groups against $N\text{-}NO_3$ such as infants.

6) Particular Note for Emergency Use

- Temporary taps will be connected to the outlet of the tank in case of the earthquake.
- Signboard should be prepared at the tank so that it shall remind people not to drink without disinfection.
- Appropriate amount of disinfectant (e.g., calcium hypochlorite) should be applied before supply.
- Laminated brief instruction manual for on-site disinfection should be prepared and kept at the site.
- Daily sprinkling work at wells in parks shall be done through new-installed tank, so that water can be kept in tank.
- Water quality of all wells designated as emergency supply bases should be monitored at regular intervals.



ID No. of Service Station	Diesel (m3)
1	45
2	47
3	46
4	45
5	44
6	48
7	49
8	90
9	45
10	45
11	45
12	31
13	40
14	47
15	45
16	42
17	42
18	24
19	45
20	45
21	90
22	45

Source: *JICA Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran (2000)*

Figure 6.4.5 Location of Service Stations Available Diesel Oil in the Study Area

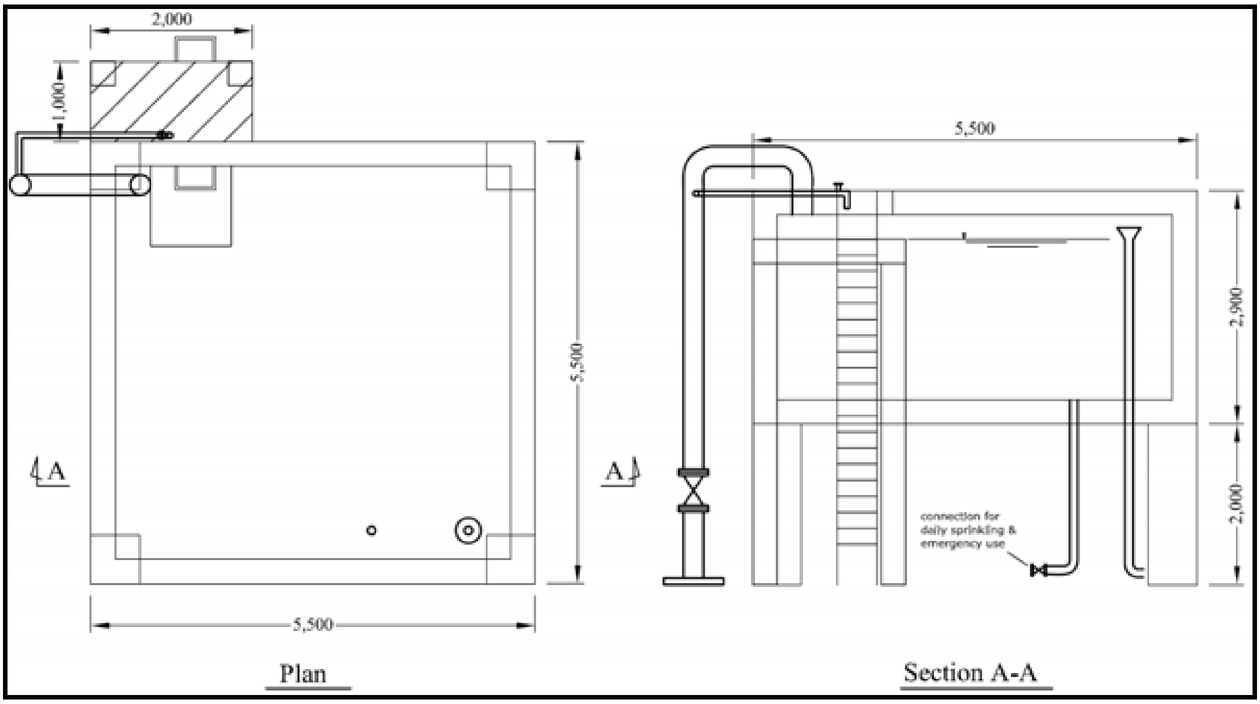
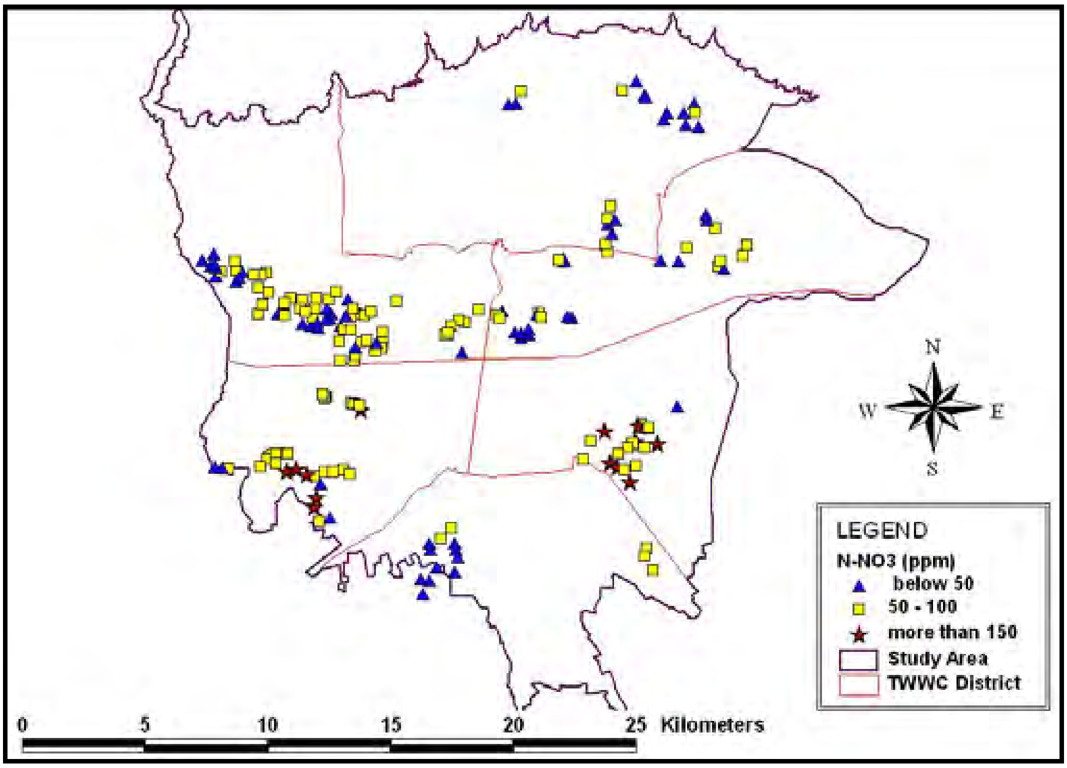


Figure 6.4.6 Example of Tanks to Be Constructed at Wells in Parks



Source: TWWC

Figure 6.4.7 Concentration of N-NO_3 for Deep Wells

(5) Supply by Water Tanker

Water tanker will be used for non-coverage area by the above mentioned water supply bases. In this Study, it is assumed that the existing water tanker will be used for emergency supply therefore cost for water tanker is not considered in the project cost estimation.

(6) Supply by Emergency Water Tank

Water will be kept in the emergency water tank in case of the earthquake. This tank is connected to distribution pipe. In normal situation, water enters into the tank from distribution pipe through inlet and exits through outlet to go back to distribution pipe. In case inflow is suspended, due to the impact of accident caused by earthquake disaster for example, in and outflow will be then suspended by the function of air valve. As a result, water will be kept in emergency supply tank. Typical size of tank to be prepared is set as $20m^3$/tank. *Figure 6.4.8* gives general feature of the emergency tank.

In this Study, installed number of emergency tank is set as following basis:

- One tank at each evacuation place designated by TDMO
- Three tanks at each well in southern part of Tehran, where concentration of N-NO_3 is relatively high as mentioned in (4).

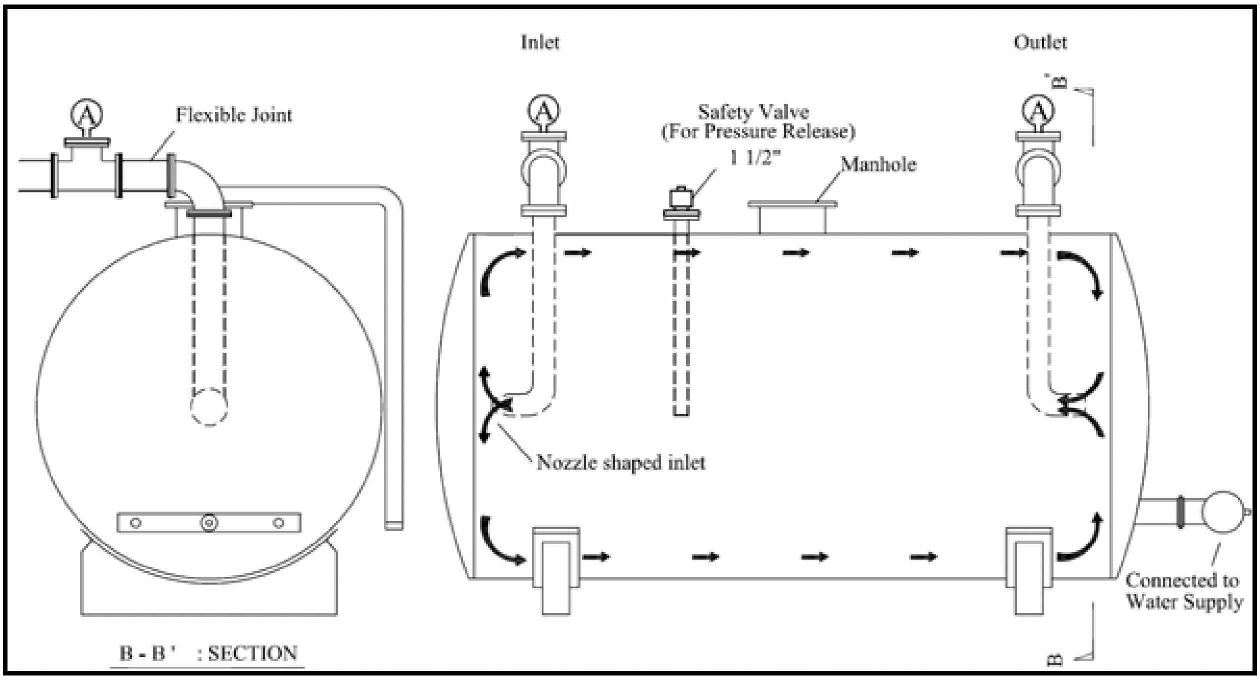


Figure 6.4.8 Example of Emergency Water Tank

6.4.2 Allocation of Emergency Water Supply Base

(1) General

In Tokyo, maximum distance to emergency water supply bases is set as 2 km. In this Study, emergency water supply bases should be allocated so that anybody can access within 1 km distance after the earthquake as mentioned in 6.4.1, considering steep geographical feature here.

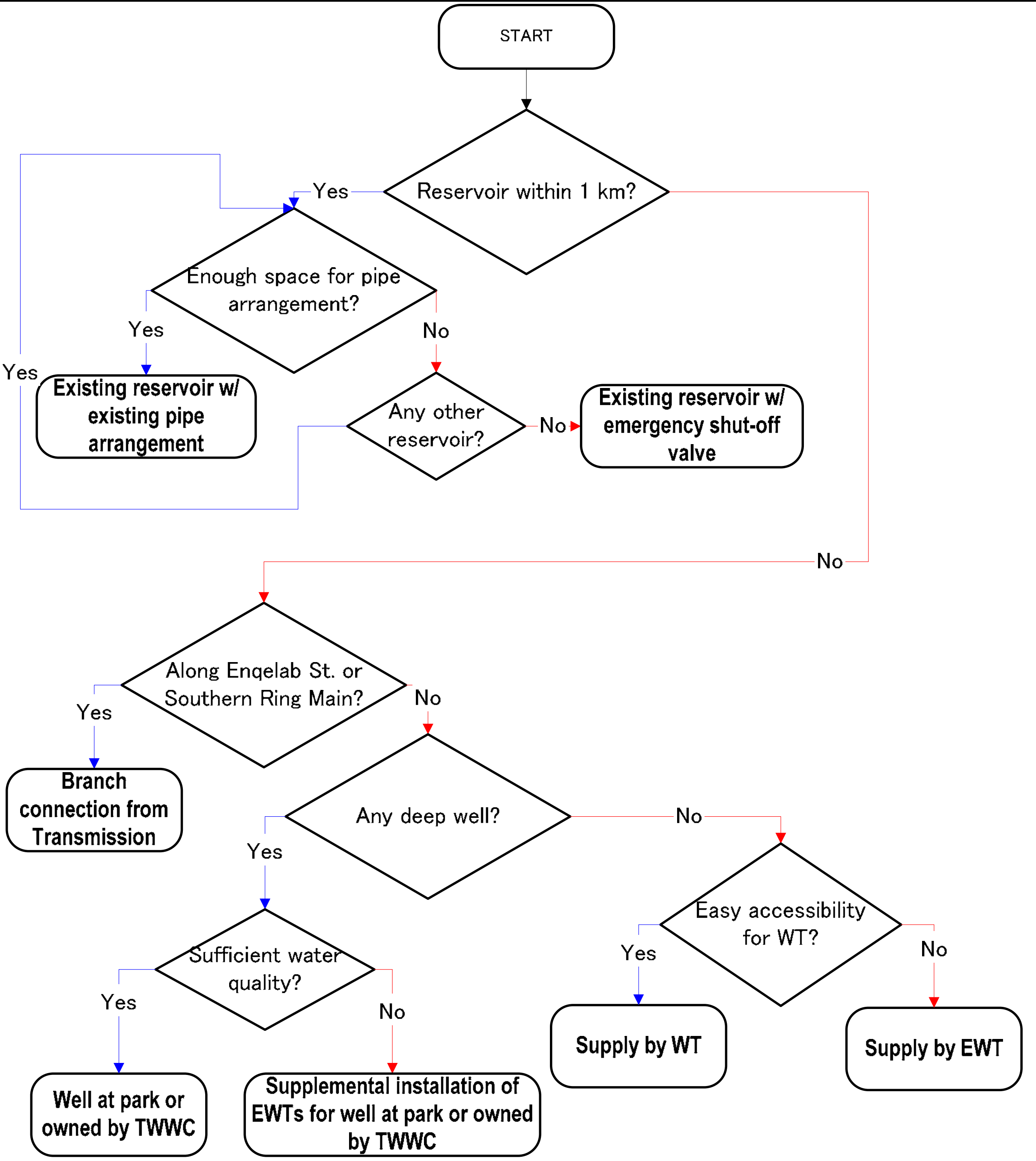
At first, emergency supply bases shall be allocated so that people can access to the base within 2 km distance in short-term planning. Then, additional bases shall be gradually allocated so that maximum access distance to the bases can be reduced to within 1 km in the medium and long term planning.

(2) Procedure of Allocation

As discussed in 6.4.2, priority for application of emergency supply method is decided as following order:

- Supply from existing reservoir with the arrangement of siphon at outlet pipe
- Supply from existing reservoir with the installation of emergency shut-off valve
- Supply from gravity transmission main of Enqelab St. and Southern Ring Main
- Supply from deep well in park
- Supply from deep well owned by TWWC
- Supply by water tanker
- Supply by emergency water tank

Figure 6.4.9 shows schematic idea and process for allocation of emergency water supply bases



Remarks:

EWT shall be installed in:

- every evacuation place designated by TDMO
- wells in park and wells owned by TWWC used as EWSB in southern part of the Tehran City, where WQ is relatively poor

Note

EWSB: emergency water supply base
EWT: Emergency Water Tank
WT: water tanker

Figure 6.4.9 Flow Diagram for Allocation of Emergency Water Supply Bases

(3) Allocation of Emergency Water Supply Base

As mentioned in (1), emergency water supply bases will be allocated in a phased manner. *Figure 6.4.10* shows allocation of supply bases after completion of short-term project. *Figure 6.4.11* shows the final shape of the planning for allocation of supply bases after the completion of medium and long-term project.

Table 6.4.2 outlines the numbers of required emergency supply bases to be allocated.

Table 6.4.2 Required Number of Emergency Supply Bases by Type and Planning Phase

Type of supply points		*Number*		
		Short-term	*Mid & long-term*	*Total*
1	Existing reservoir (Outlet arrangement)	30	18	48
2	Existing reservoir (Emergency shut-off valve)	0	3	3
3	Gravity transmission (Southern Ring Main & Enqelab St.)	11	7	18
4	Deep well (owned by TWWC)	0	27	27
5	Deep well (in Park)	22	37	59
6	Emergency water tank	32	169	201

(4) Particular Notes in Allocation of Emergency Water Supply Base in Short-term Planning

As mentioned above, emergency water supply bases should be firstly prepared so that anybody can access within 2 km distance after the earthquake in short term planning and subsequently additional bases should be allocated so that the maximum access distance can be reduced to 1 km in medium and long-term planning. However, in fact, nobody can predict precisely when or where a massive earthquake strikes.

In order to be prepared for unexpected disaster, it is necessary to give higher priority in allocation of supply base to the area where the extent of damage is severer than the other areas, with the consideration of damage under all possible earthquake scenarios.

Therefore, it is recommended that prioritization for the sequence of construction of the emergency water supply bases should be considered in the short-term planning as well.

In the course of determination of priority, following items should be considered:

- The area where number of supply interrupted population would be greater (a).
- The area where destruction of houses would be severer (b).
- The area where power supply suspension would be prolonged (c).
- The area where water tanker cannot access because the road does not have enough space (d).

Taking account for the above (a), for example, the sequence of construction for supply bases can be proposed as following order (refer to *Table 6.4.3*). Here, 4 earthquake scenarios are considered in prioritization of construction sequence of emergency supply bases:

- The area where supply interrupted population tops more than 10,000 under either of 3 scenarios (reservoir zone 2, 3, 4, 6 and 36)
- The area where supply interrupted population tops more than 10,000 under either of 2 scenarios (reservoir zone 1, 8, 10, 15-16-53, 18, 19, 20, 23, 26, 28, 31, 41, 62)
- Other areas

As for the other above items of (b), (c) and (d), it is recommended that prioritization should be examined with reference to the previous relevant study report, such as the study report on electricity sector or JICA Microzoning Study, for example.

Table 6.4.3 Supply Interrupted Population by Earthquake Scenario

Reservoir Zone		Initial Supply Interruption Population by Scenario				Number of Zones where Supply Interrupted Population Exceeds 10,000
Zone No.	Population	N.tehran	S.ray	N.ray	Mosha	
1	90,017	90,017	0	2,488	90,017	2
2	275,753	275,753	18,417	36,755	275,753	4
3	177,147	17,160	16,857	25,440	0	3
4	159,628	16,339	15,352	21,940	2,792	3
5	128,276	6,804	8,444	7,644	2,706	0
6	261,615	14,362	11,545	17,511	0	3
7	337,737	1,832	0	0	0	0
8	136,112	136,112	0	0	136,112	2
10	50,910	50,910	0	0	50,910	2
11	120,856	2,842	0	0	0	0
12	24,225	24,225	0	0	0	1
13	285,713	285,713	0	168	0	1
14	42,081	42,081	0	0	0	1
15A	72,130	0	0	120	0	0
15−16−53	692,367	19,387	5,447	310,392	649	2
18	26,275	26,275	0	0	26,275	2
19	122,573	122,573	0	0	122,573	2
20	86,009	86,009	0	0	14,912	2
21	118,916	118,916	0	0	396	1
22	75,741	75,741	0	0	0	1
23	32,491	32,491	0	0	10,772	2
24	49,531	49,531	0	0	0	1
26	53,525	53,525	0	0	23,805	2
27	36,623	36,623	0	0	5,865	1
28	18,078	18,078	0	0	11,522	2
29	15,824	15,824	0	0	0	1
30	5,383	5,383	0	0	0	0
31	255,237	255,237	0	0	255,237	2
32	10,384	10,384	0	0	0	1
33	1,376	1,376	0	0	282	0
36	196,826	168,424	99,312	124,362	2,191	3
37	93,452	83,626	0	0	0	1
38	85,076	85,076	0	0	0	1
39	13,142	13,142	0	0	0	1
40	34,717	34,717	0	0	0	1
41	90,210	90,210	0	0	28,245	2
42	44,993	44,993	0	0	0	1
43	319,863	319,863	0	0	94	1
45	26,845	26,845	0	0	224	1
48	37,245	37,245	0	0	3,099	1
51	292,094	292,094	0	133	0	1
54	142,613	142,613	0	0	0	1
55	104,174	104,174	0	0	0	1
56	124,225	124,225	0	0	0	1
57	94,222	0	0	0	0	0
58	87,938	28,805	0	0	0	1
59	42,162	3,109	0	0	0	0
9−61	84,050	84,050	0	0	0	1
62	72,069	72,069	0	0	72,069	2
63	153,997	0	0	3,945	0	0
64	41,724	41,724	0	750	0	1
65	101,044	0	7,123	54,584	0	1
66	93,290	0	155	36,141	0	1
67	81,179	0	412	30,337	0	1
68	119,046	0	0	7,497	0	0
69	44,619	0	0	0	0	0
70	87,759	0	0	0	0	0
71	65,316	65,316	0	0	0	1
72	61,916	61,916	0	0	0	1
74	45,062	45,062	0	0	0	1
75	36,617	36,617	0	0	122	1
77	36,703	36,703	0	0	0	1
80	86,870	1,997	0	0	0	0
81	76,708	0	0	0	0	0
82	41,955	41,955	0	0	0	1
91	16,480	16,480	0	0	0	1

Note: (shaded, bold border) Supply interrupted population (10,000 and over)
(shaded) Supply interrupted population (1 to 9,999)

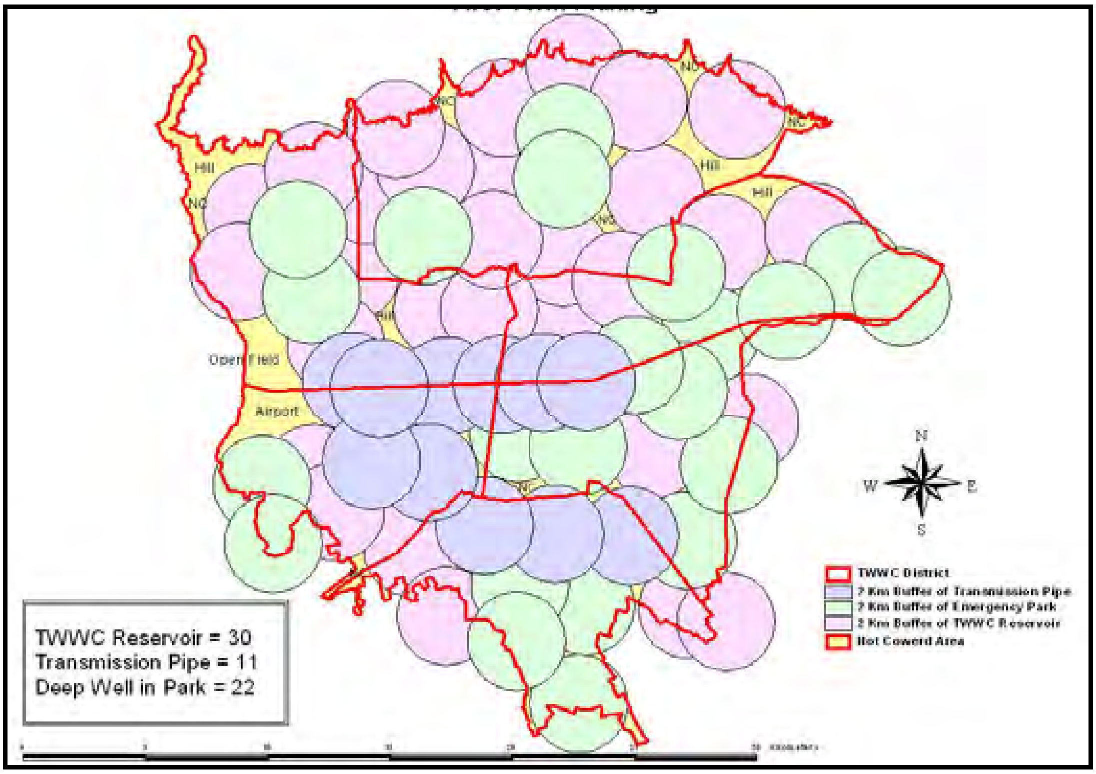


Figure 6.4.10 Allocation of Emergency Supply Bases after Completion of Short-term Planning

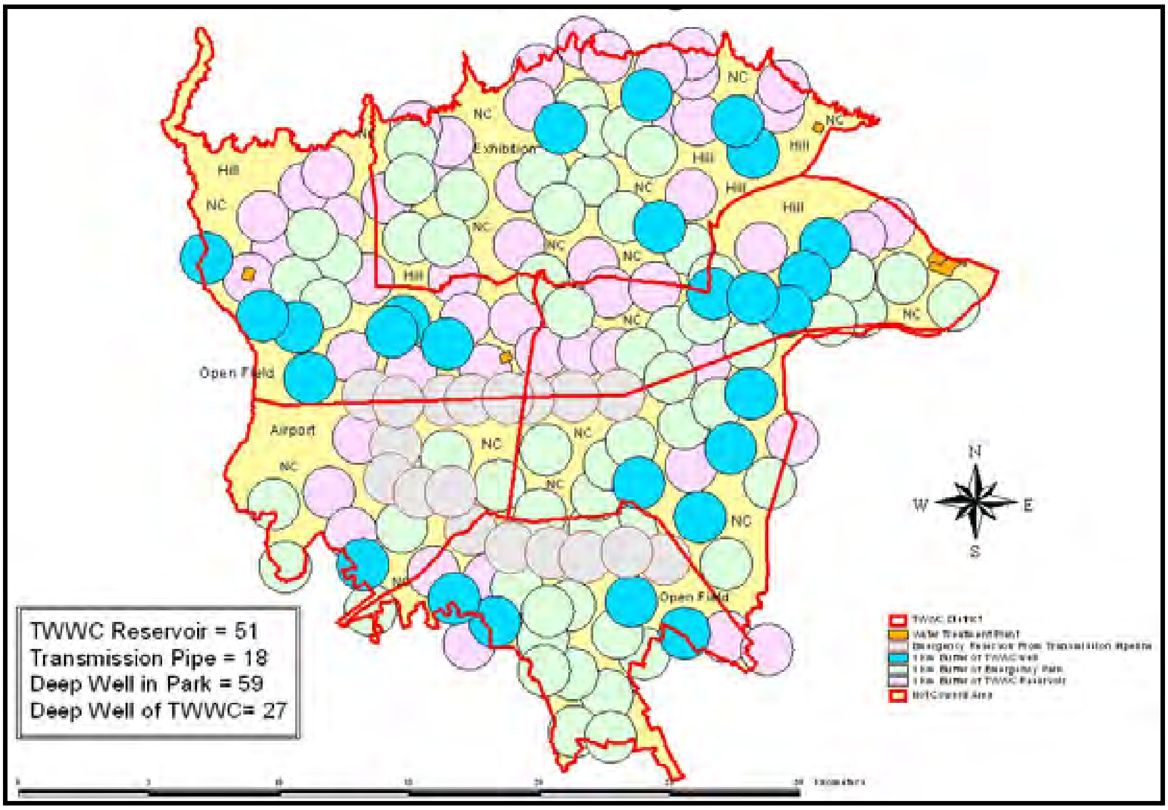


Figure 6.4.11 Allocation of Emergency Supply Bases after Completion of Mid & Long-term Planning

CHAPTER 7 DEVELOPMENT OF DRAFT EMERGENCY PLAN

7.1 Supply Interrupted Population and Restoration Period

A large scale earthquake cuts the lifelines of water service, electricity and gas. It cause destruction of buildings and the roads, and bring a large influence to the citizens' lives. The victim will receive a large pain. Therefore, TWWC is required to supply water at the earliest stage by using limited number of manpower, material and equipment.

Damage on the water service can be minimized by making all the facilities earthquake-proof. However, it requires long time and huge amount of money for the execution since lots of facilities should be reinforced. It is important to take adequate anti-earthquake measures, which consider the balance of facility reinforcement and the emergency measures.

It is, at first, required to understand the quantitative influence to the residents by earthquake, and then evaluate the effects of several anti-earthquake measures. Accumulated water supply interrupted population for the recovery period, which is calculated as “interrupted population” times “restoration period”, is used as an index for the evaluation.

7.1.1 Definition of Damage Estimation as a Water Supply System

The water supply system of Tehran is composed of intake facilities, raw water transmission mains, clear transmission mains, water treatment plants, distribution mains and service connections. A large number of consumers will be affected when upstream of the system is damaged. The more upstream the damage is, the more number of consumers are affected.

That is to say:

- When a power plant stops, it will influence the waterworks facilities (water treatment plants).
- When raw water transmission mains are damaged, water treatment plants at downstream will be affected.
- When water treatment plants or transmission mains or pumping houses are damaged, water distribution reservoirs at downstream will be affected.
- When pumps and pipes of wells are damaged, reservoir at downstream will be affected.
- When reservoirs and distribution trunk mains are damaged, reservoir zone at downstream will be affected.
- When distribution sub mains and service connections are damaged, customers at downstream will be affected.

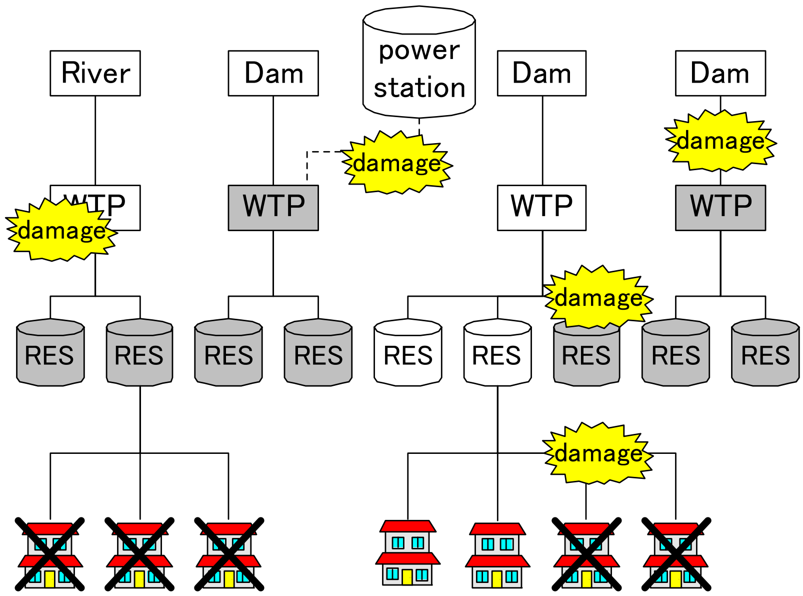


Figure 7.1.1 Image of Damage Effect to Other Facilities

It is not appropriate to judge the damage of water supply system from damage of each individual structure and pipeline. As shown in *Figure 7.1.1* it is necessary to understand the extent of the impact and the scale of damage as a water supply system, in which water flows from raw water intake to the service connection.

7.1.2 Damage Estimation as the Whole Water Supply System of TWWC

In this study, four scenario earthquakes of North Tehran, North Ray, South Ray, and Mosha are assumed, and the earthquake movement analysis, the earthquake-proof diagnosis investigation of the structure, and estimation of damage on pipes are evaluated.

Among the four scenario earthquakes, the North Tehran earthquake will cause the largest and the most serious damage on the water supply facilities, and then damage in this scenario is discussed in this section.

Table 7.1.1 shows the structures with high possibility of damage, while the estimation of damage on pipeline is summarized in *Table 7.1.2* and its details are explained in previous section. *Table 7.1.3* shows number of damage in each transmission main network system. *Table 7.1.4* shows number of damage in each reservoir zone.

Table 7.1.1 Structures with High Possibility of Damage

Division	Facilities no
Water Treatment Plant	WTP No.3-No.4（Reservoir No.71、No.95、No.97） WTP No.5
Reservoir and Pump Building	Reservoir No.11 Reservoir No.14 and pump house Reservoir No.26 and pump house Reservoir No.75 and pump house Reservoir No.77 Reservoir No.82

Table 7.1.2 Estimation of Damage on Pipes

Type of Pipe	Number of Damage	Calculation grounds
(1)Transmission main	22	Damage on active fault：22 places Whether pipes will be damaged or not is judged based on the pipelines with high possibility of damage, which is described in previous section 6.2.
(2)Distribution trunk main （X≧φ300mm）	66	The number is total of damage on active fault as described in previous section 6.2.
(3)Distribution Sub-main （X＜φ300mm）	707	The number is total of damage on active fault and forecast number by damage function type as described in previous section 6.2.
(4)Service connection	3,865	5.0 times of the damage on distribution mains are considered based on the data of Hanshin-Awaji (Kobe) Earthquake b＋c：d＝1：5 （Appendix -9.1 references）
Total	4,660	Total of (1),(2), (3) and (4).

Table 7.1.3　　Damage Point of Transmission Main Network System

water treatment plant	transmission mainne twork system	damage point				total
		transmission main	distribution main	distribution sub main	service connection	
WTP No.1	WTP-1_gravity	0	9	0	45	54
	WTP-1_pump	8	10	95	525	638
WTP No.2	WTP-2_gravity1	1	2	0	10	13
	WTP-2_gravity2	2	6	19	125	152
	WTP-2_pump1	3	4	70	370	447
	WTP-2_pump2	0	0	2	10	12
WTP No.3	WTP-3-4_gravity1	2	4	42	230	278
WTP No.4	WTP-3-4_gravity2	2	2	41	215	260
WTP No.5	WTP-5_gravity	4	17	380	1,985	2,386
Well	WELL_east	0	1	6	35	42
	WELL_west	0	11	52	315	378
total		22	66	707	3,865	4,660

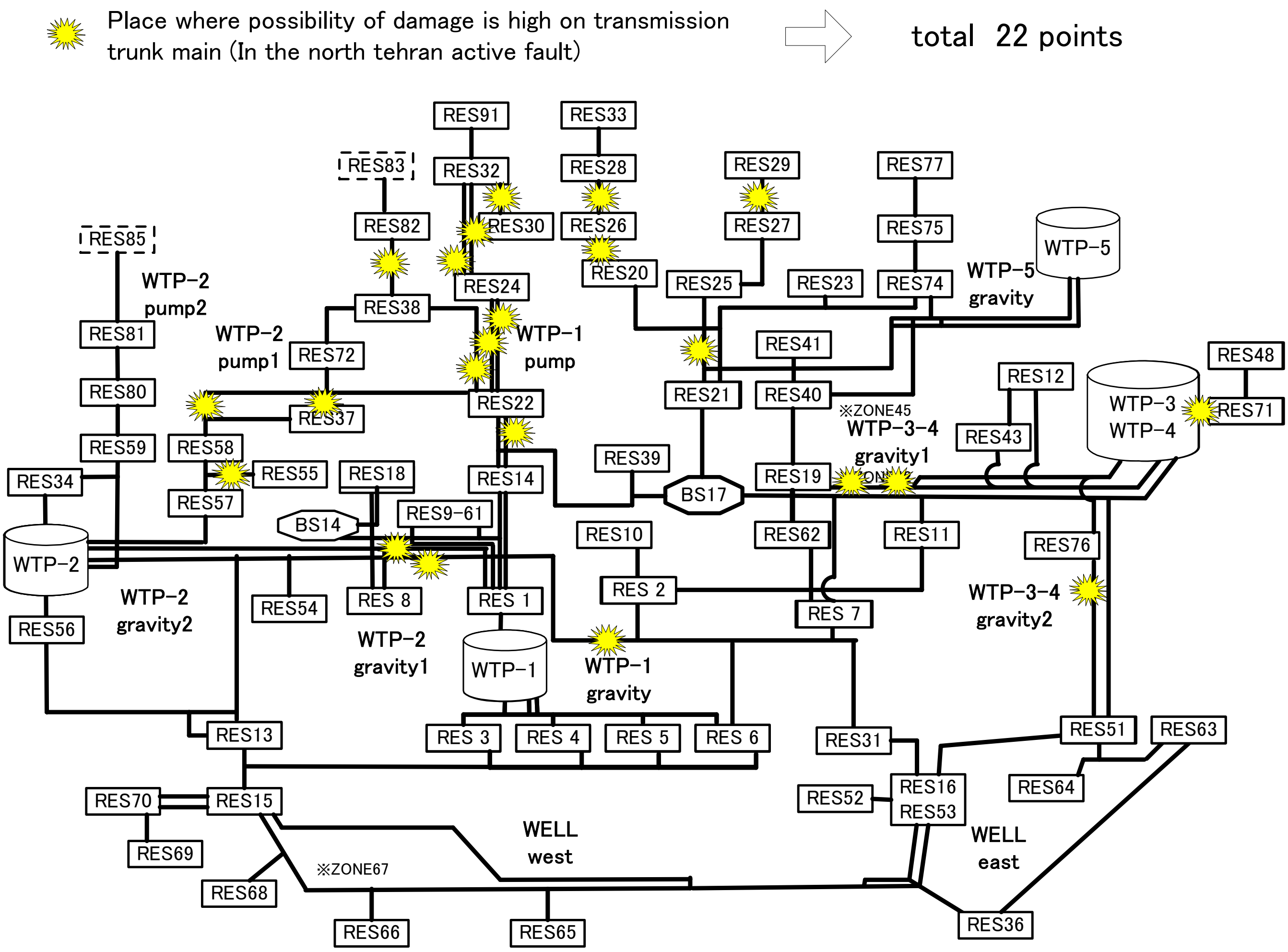


Figure 7.1.2　　Damage Place in Transmission Main

Table 7.1.4 Number of Damage in Each Reservoir Zone

reservoir-zone	distribution trunk main	distribution sub main	service connection	total	remarks column
1	1	0	5	6	
2	6	11	85	102	
3	2	0	10	12	
4	3	0	15	18	
5	2	0	10	12	
6	2	0	10	12	
7	0	1	5	6	
8	1	0	5	6	
10	0	8	40	48	
11	0	1	5	6	
12	0	0	0	0	
13	0	0	0	0	
14	0	5	25	30	
15A	0	0	0	0	
15-16-53	1	6	35	42	
18	0	0	0	0	
19	1	5	30	36	
20	1	99	500	600	
21	2	23	125	150	
22	0	41	205	246	
23	0	34	170	204	
24	6	9	75	90	
26	0	60	300	360	
27	2	42	220	264	
28	0	56	280	336	
29	1	6	35	42	
30	0	6	30	36	
31	0	0	0	0	
32	1	8	45	54	
33	0	6	30	36	
36	11	52	315	378	
37	2	28	150	180	
38	2	4	30	36	
39	0	4	20	24	
40	1	16	85	102	
41	9	38	235	282	
42	0	2	10	12	
43	3	33	180	216	
45	1	14	75	90	
46					Unfinished region of pipe
48	0	5	25	30	
51	0	2	10	12	
54	0	0	0	0	
55	0	17	85	102	
56	0	0	0	0	
57	0	0	0	0	
58	0	6	30	36	
59	0	1	5	6	
9-61	0	0	0	0	
62	0	10	50	60	
63	0	0	0	0	
64	0	0	0	0	
65	0	0	0	0	
66	0	0	0	0	
67	0	0	0	0	
68	0	0	0	0	
69	0	0	0	0	
70	0	0	0	0	
71	0	1	5	6	
72	2	19	105	126	
74	0	4	20	24	
75	1	4	25	30	
77	1	1	10	12	
78					reservoir zone of the future
79					reservoir zone of the future
80	0	1	5	6	
81	0	0	0	0	
82	0	9	45	54	
83					reservoir zone of the future
84					reservoir zone of the future
85					reservoir zone of the future
91	1	9	50	60	
total	66	707	3,865	4,638	The damage of transmission trunk main is added →total 4,660

7.1.3 Estimation of Supply Interrupted Population and Restoration Period

(1) Definition of Estimation of Supply Interrupted Population and the Restoration Period

1) Precondition of Restoration Simulation

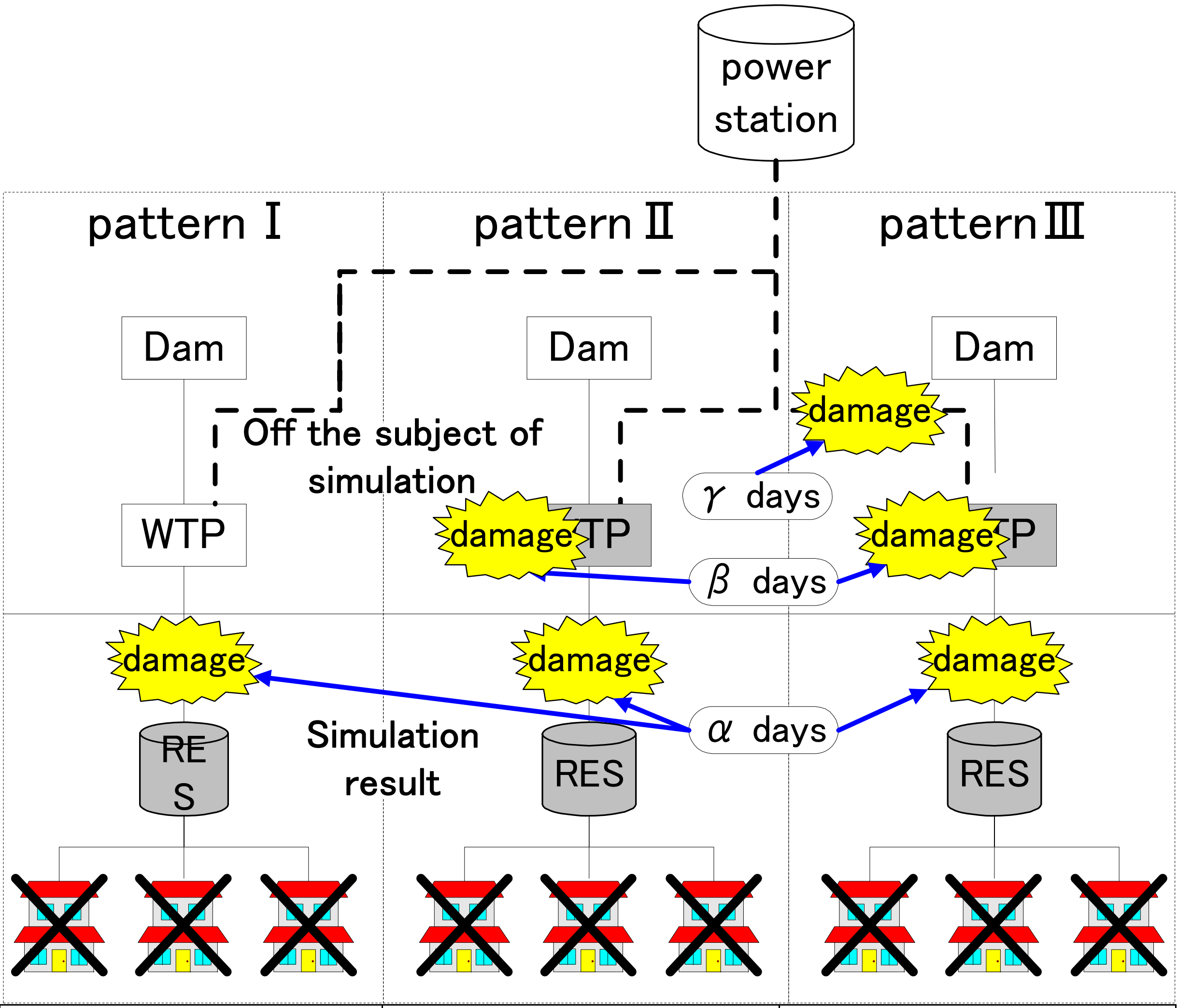
The restoration simulation is done to examine the effects of several anti-earthquake measures by using the indicator of total interrupted population for influence level. It is required to understand the quantitative influence to the resident by the earthquake. *Table 7.1.5* shows the precondition concerning the restoration simulation.

Table 7.1.5 Precondition of Emergency Restoration Simulation

Item	Content considered by restoration simulation		Content that can be considered outside of restoration simulation
	Before measures	After measures	
(a) Power plant	Off the subject	Off the subject	The power plant stops for about one week because of the influence due to the earthquake.
(b) Installation of disaster headquarters	For about one week immediately after the earthquake (Period that requires it to establish the first moving system)	For about three days immediately after the earthquake(Because the first moving system is maintained, the period is shortened.)	
(c) Well	It is possible to use it.	It is possible to use it.	
(d) Raw water transmission main	Off the subject	Off the subject	Water treatment plant in the down-stream stops for a certain period.
(e) Water treatment plant	Off the subject	Off the subject	The targeted Water treatment plant stops for a certain period.
(f) Transmission main	In each water supply system, reserv-oir in the downstream of the damage part is assumed to be interrupted the water supply.	It is thought that an earthquake-proof pipe doesn't cause damage.	
(g) Distribution trunk main	Every the reservoir zone and distri-bution trunk main damage rate are assumed.	It is thought that an earthquake-proof pipe doesn't cause damage.	
(h) Distribution sub main Serivce connection	Every the reservoir zone and distri-bution sub main damage rate are assumed.	It is thought that an earthquake-proof pipe doesn't cause damage.	

When facilities have uncertainties in the functions and restoration period, they are excluded from restoration simulation.

When damages on power plant and/or raw water transmission main and/or water treatment plant are considered, water supply interrupted population (for instance, γ days × population of water supply interruption in case of the power plant) can be calculated by adding the restoration period of each facility to the result of this restoration simulation. (b) and (c) of *Table 7.1.3* and (f), (g) and (h) are considered. *Figure 7.1.3* shows an example of the calculation.



The number of required days for restoration is obtained from the results of simulation.	Consideration of the restoration period of the filtration plant. ↓ The required days for restoration (α + β) days	Consideration of the restoration period of the power plant and water treatment plant. ↓ The required days for restoration (α +β +γ) days

Figure 7.1.3 Idea of the Required Days for Restoration and the Water Supply Interrupted Population in which External Factor is Considered

2) Calculation procedure of restoration simulation

Figure 7.1.4 shows the calculation procedure of the restoration simulation. The method of using this simulation is described below.

- To calculate water supply interrupted population and the required days for restoration “before taking countermeasures”

- To calculate the water supply interrupted population and the required days for restoration “after taking countermeasures” by comparing the target of facility reinforcement and required days for restoration.

- To evaluate accumulated water supply interrupted population for the period (= the water supply interrupted population ×required days for restoration) “before” and “after” taking countermeasures and to evaluate the measures.

Hereinafter this paper explains a) Setting of population of each reservoir zone, b) Setting of transmission main network system, c) Setting of organization for restoration of pipeline, d) Calculation of restoration process, and e) Calculation of the water supply interrupted population.

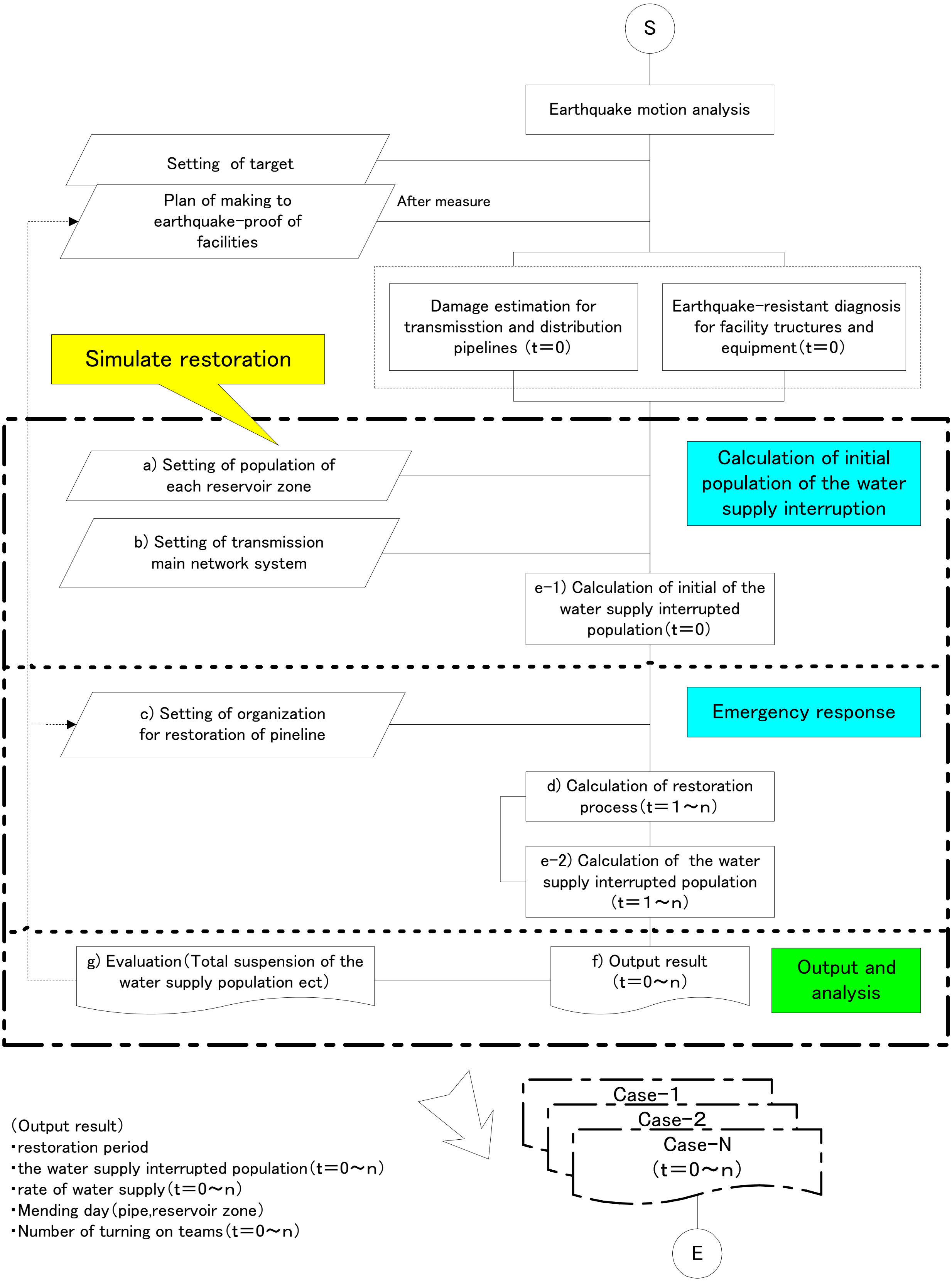


Figure 7.1.4 Calculation Procedure of Restoration Simulation

a) Setting of population of each reservoir zone

The population of 6,938,734 persons in Tehran City in 2005 (Information of Iran Statistics data, District 21-22 were excluded) is allocated to each reservoir zone for the analysis as shown in *Table 7.1.6*.

Table 7.1.6 Population of Each Reservoir

reservoir no	number of person of person2005		remarks column
	before measures	after measures	
1	90,017	90,017	
2	275,753	275,753	
3	177,147	177,147	
4	159,628	159,628	
5	128,276	128,276	
6	261,615	261,615	
7	337,737	337,737	
8	136,112	136,112	
10	50,910	50,910	
11	120,856	120,856	
12	24,225	24,225	
13	285,713	285,713	
14	42,081	42,081	
15A	72,130	72,130	
15-16-53	692,367	692,367	
18	26,275	26,275	
19	122,573	122,573	
20	86,009	86,009	
21	118,916	118,916	
22	75,741	75,741	
23	32,491	32,491	
24	49,531	49,531	
26	53,525	53,525	
27	36,623	36,623	
28	18,078	18,078	
29	15,824	15,824	
30	5,383	5,383	
31	255,237	255,237	
32	10,384	10,384	
33	1,376	1,376	
36	196,826	196,826	
37	93,452	93,452	
38	85,076	85,076	
39	13,142	13,142	
40	34,717	34,717	
41	90,210	90,210	
42	44,993	44,993	
43	319,863	319,863	
45	26,845	26,845	
46		23,174	a part before measures to Res74
48	37,245	37,245	
51	292,094	292,094	
54	142,613	142,613	
55	104,174	104,174	
56	124,225	124,225	
57	94,222	94,222	
58	87,938	87,938	
59	42,162	42,162	
9-61	84,050	84,050	
62	72,069	72,069	
63	153,997	153,997	
64	41,724	41,724	
65	101,044	101,044	
66	93,290	93,290	
67	81,179	81,179	
68	119,046	119,046	
69	44,619	44,619	
70	87,759	87,759	
71	65,316	65,316	
72	61,916	61,916	
74	45,062	21,888	
75	36,617	36,617	
77	36,703	18,306	
78		16,468	a part before measures to Res77
79		1,929	a part before measures to Res77
80	86,870	86,870	
81	76,708	42,762	
82	41,955	27,321	
83		14,634	a part before measures to Res82
84		18,796	a part before measures to Res81
85		15,150	a part before measures to Res81
91	16,480	16,480	
計	6,938,734	6,938,734	

Source : Iran Statistics data 2005(District21-22 is excluded)

b) Setting of transmission main network system

Figure 7.1.5 shows transmission main network system. It is classified by transmission main network system from each of the water treatment plant, during daily maximum water supply (as of July 19th 2005).

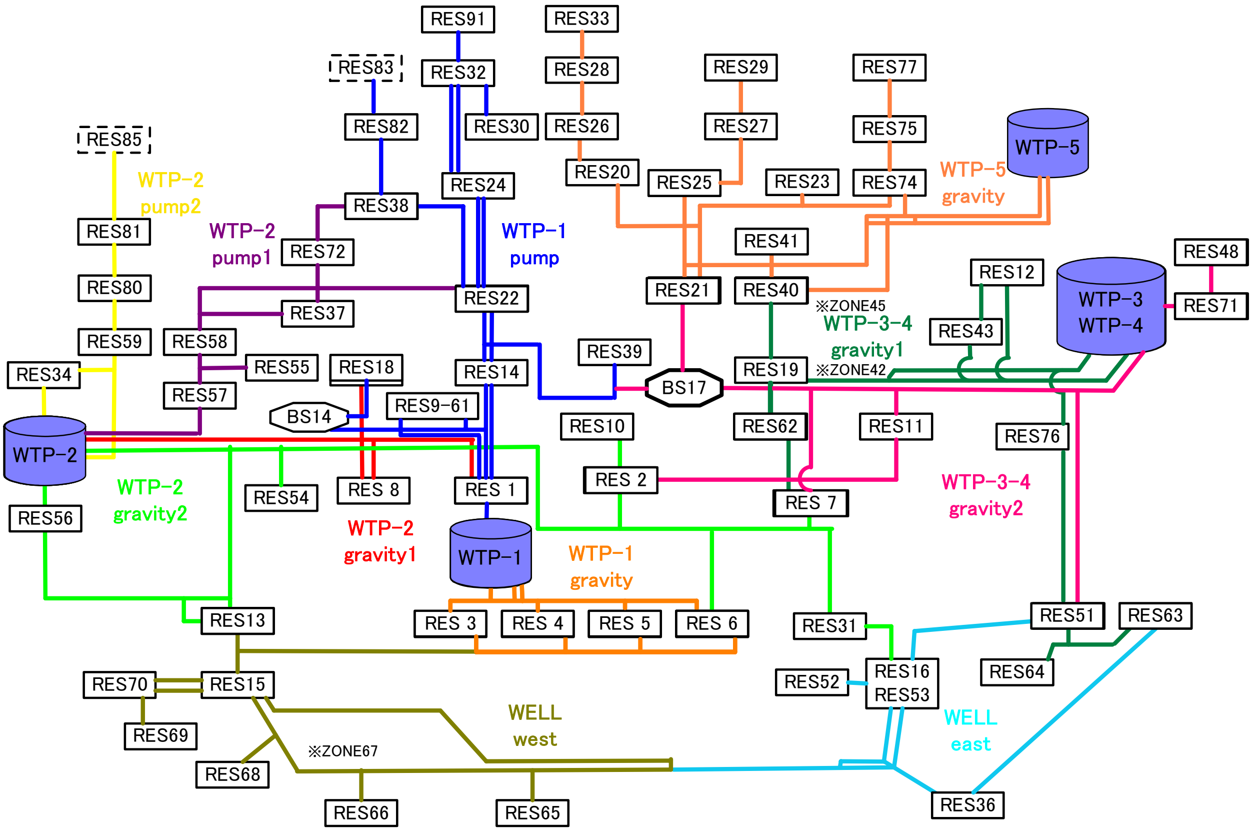


Figure 7.1.5 Transmission Main Network System

c) Setting of system of recovery efforts

The organization for pipe repair works is set as *Table 7.1.7* based on the hearing results from TWWC. The hearing revealed that transmission mains are repaired by TWWC head office and Water District offices are responsible for distribution trunk mains, distribution sub mains, and service connections.

Table 7.1.7 Organization for Pipe Repair Works

Type of pipe	Manager	Number	Grounds
Transmission main	TWWC head office	3 teams	System of recovery of transmission main One team is composed of 12 persons
Distribution trunk-main	Water Districts	18 teams	It sets it in consideration of the number of heavy equipment. 6districts×3 post One team is composed of 12 persons
Distribution Sub-main	Water Districts	54 teams	6 districts×3 post×3team One team is composed of 12 persons
Service connection	Water Districts	108 groups	6 districts×3 post×3team×2group One team is composed of 3-4 persons

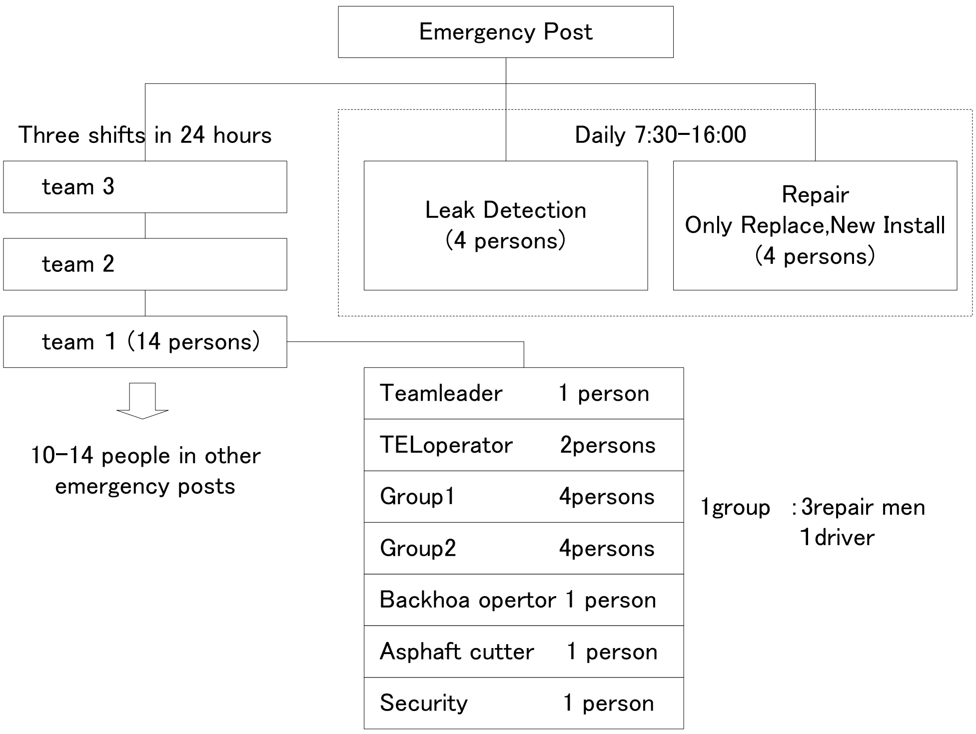


Figure 7.1.6 Organization of Emergency Post（Information of district 5）

d) Calculation of restoration process

The restoration simulation calculates the daily change of numbers of damage immediately after the earthquake (t=0) up to restoration completion day (t=N). The basic idea of the restoration simulation is described below.

Basic idea to simulate restoration

- One week is assumed for the period for calling staffs, collecting damage information, and establishment of restoration organization "before taking countermeasures". It is set as three days "after taking countermeasures", such as preparation of manual and improvement of staff's wills.
- Pipe restoration teams are distributed to each transmission main network system at the rates of damage number as shown in *Table 7.1.3*.
- The pipes are considered to be repaired from upstream to downstream (i.e., transmission main→ distribution trunk main→distribution sub main→service connection). It is assumed that two teams cannot work at one time on the same pipeline since restoration work of transmission line and distribution mains should be done from upstream to downstream.
- The restoration period of pipe repair at one place is set as twice of the usual restoration period, which information is obtained by hearing of TWWC, in consideration of difficulties in a traffic condition after earthquake due to building collapse, interruption of the road and others.

The results the simulation are shown in *Table 7.1.8.*

Table 7.1.8 Required Period for Pipe Restoration

Type of pipe	Diameter of pipe	Required period for restoration
Transmission main	X≧φ600mm φ600mm＞X≧φ300mm	0.33 Part/day/team 0.5 Part/day/team
Distribution trunk main	X≧φ300mm	0.5 Part/day/team
Distribution Sub main	X＜φ300mm	1.0 Part/day/team
Service connection		2.0 Part/day/team

e) Calculation of the water supply interrupted population

Water supply interrupted population is calculated from "the population of each reservoir zone" and "damage rate of pipe" of transmission main, distribution trunk main, distribution sub-main, and service connection. A basic idea for the calculation of the water supply interrupted population is described below.

Basic Idea for Calculation of Water Supply Interrupted Population

- Water supply interrupted population is calculated based on the damage rate of pipe of transmission mains, distribution trunk mains, distribution sub-mains, and service connections.

- The damage of power plants, raw water transmission mains, water treatment plants, reservoirs, and pump houses are excluded from the restoration simulation.

- When transmission main is damaged, water supply in all downstream reservoir zones is assumed to be interrupted.

- When transmission main is not damaged, the damage rate of reservoir zone is calculated by using the damage rate of distribution trunk mains and the damage rate of distribution sub-mains.

The water supply rate of interrupted reservoir zone
　＝ 1 － （1－damage rate of distribution trunk mains） × （1－damage rate of distribution sub mains）

The water supply interrupted population in reservoir zone
　= population of reservoir zone × the water supply rate of interrupted reservoir zone

(2)The analysis results

The outline of Case Study and the output of the study, such as water supply interrupted population, required days for restoration days and recovery efforts team, in each case are explained below.

1) Case study

In order to achieve the target restoration period of one month, suitable countermeasures, which consider balance of reinforcement and emergency measures, are examined by restoration simulation. Conditions of the simulation of each case for the case study are summarized in *Table 7.1.9.*

Table 7.1.9 Conditions of Simulation for Each Case

CASE-1	Without Any Countermeasures
CASE-2	When transmission mains are earthquake-proof
CASE-3	When transmission mains are earthquake-proof and the number of restoration team is increased.
CASE-4	When transmission mains are earthquake-proof and active fault measures are adopted in distribution trunk mains
CASE-5	When transmission mains are earthquake-proof and active fault measures are adopted in distribution trunk mains and distribution sub mains.

The number of damage for each case is summarized in *Table 7.1.10.* The number of damaged locations in transmission mains is 0 in CASE-2-CASE-5 after taking countermeasures, while it is 22 in CASE-1 before taking countermeasures. The number of damage locations in distribution trunk mains is 3 in CASE-4 when the active fault measures of distribution trunk mains are adopted, and CASE-5 when the active fault measures of distribution trunk mains and distribution sub mains are adopted. Moreover, the damage number of water distribution sub-mains in CASE-5, which considers countermeasures of distribution sub mains on active fault, is 533.

Table 7.1.10 Damage Number of Each Case

No	transmission main	distribution trunk main	distribution sub main	survice connection	total
	(number)	(number)	(number)	(number)	(number)
CASE-1	22	66	707	3,865	4,660
CASE-2	0	66	707	3,865	4,638
CASE-3	0	66	707	3,865	4,638
CASE-4	0	3	707	3,865	4,575
CASE-5	0	3	533	3,865	4,401

2) The water supply interrupted population and required period for restoration

The water supply interrupted population and required period (days) for restoration in each case study are shown in *Table 7.1.11*. In CASE-1, initial water supply interrupted population is 3,995 thousand (rate 57.6%) and accumulated interrupted population throughout the period is 125,770 thousand while the restoration period is 82 days.

In CASE-2, initial interrupted population is 1,739 thousand (25.0%) and accumulated interrupted population throughout the period is 64,483 thousand while the restoration period is 73 days.

In CASE-3, initial interrupted population is 1,739 thousand (25.0%) and accumulated interrupted population throughout the period is 29,728 thousand while the restoration period is 30 days.

In CASE-4, initial interrupted population is 1,640 thousand (23.6%) and accumulated interrupted population throughout the period is 48,382 thousand while the restoration period is 65 days.

In CASE-5, initial interrupted population is 1,591 thousand (22.9%) and accumulated interrupted population throughout the period is 45,015 thousand while the restoration period is 60 days.

Table 7.1.11 The Water Supply Interrupted Population and Required Days for Restoration

No	the water supply interrupted population			required days for restoration
	Initial (1000 person)	Initial rate (%)	total (1000 person)	(day)
CASE-1	3,995	57.6	125,770	82
CASE-2	1,739	25.0	64,483	73
CASE-3	1,739	25.0	29,728	30
CASE-4	1,640	23.6	48,382	65
CASE-5	1,591	22.9	45,015	60

※Initial rate＝initial water supply interrupted population ÷6,938,734 people（Information of Iran Statistics data）×100

Figure 7.1.7 shows the transition of the water supply interrupted population and restoration rate in each case. In CASE-1, restoration work of transmission main will be completed on the 7th day, and repair of distribution trunk main will be completed on the 38th day. On the other hand, distribution trunk main is restored on the 22nd day in CASE-2 (about 1/2 of CASE-1), and restored on the 13th day in CASE-3-CASE-5 (about 1/3 of CASE-1).

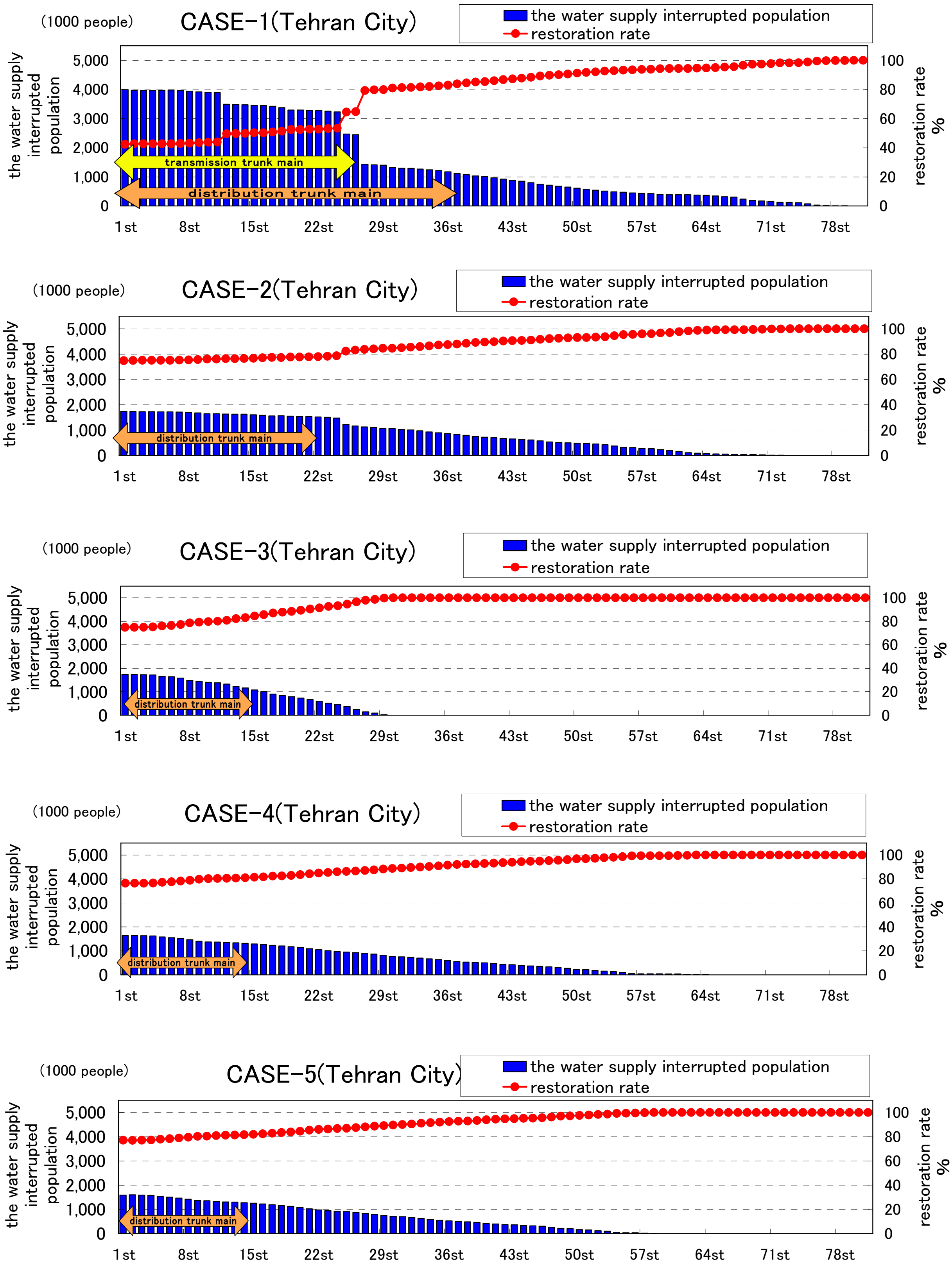


Figure 7.1.7 Transition of the Water Supply Interrupted Population of Case Study

The transition of the water supply interrupted population in each reservoir zone is shown in *Figure 7.1.8*-*Figure 7.1.9* (CASE-1 and CASE-3). Moreover, the transition of the water supply interrupted population in each transmission main network system is shown in APPENDIX- 9.2. The water supply interrupted population in each reservoir zone system is shown in APPENDIX- 9.3. To understand the assumed damage region in APPENDIX-9.3, the water supply interrupted population of four scenario earthquakes is shown.

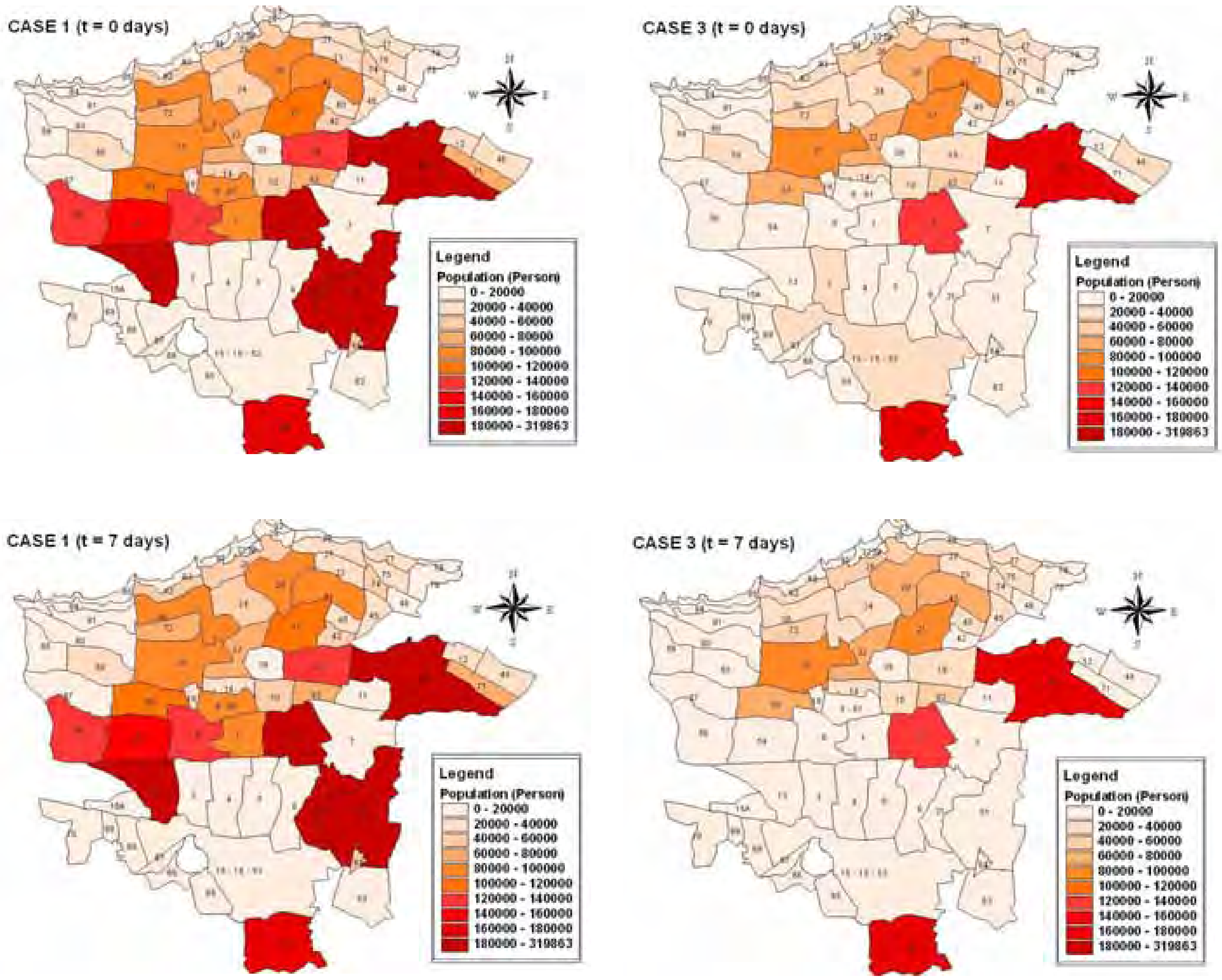


Figure 7.1.8 Water Supply Interrupted Population（t=0 and t=7）

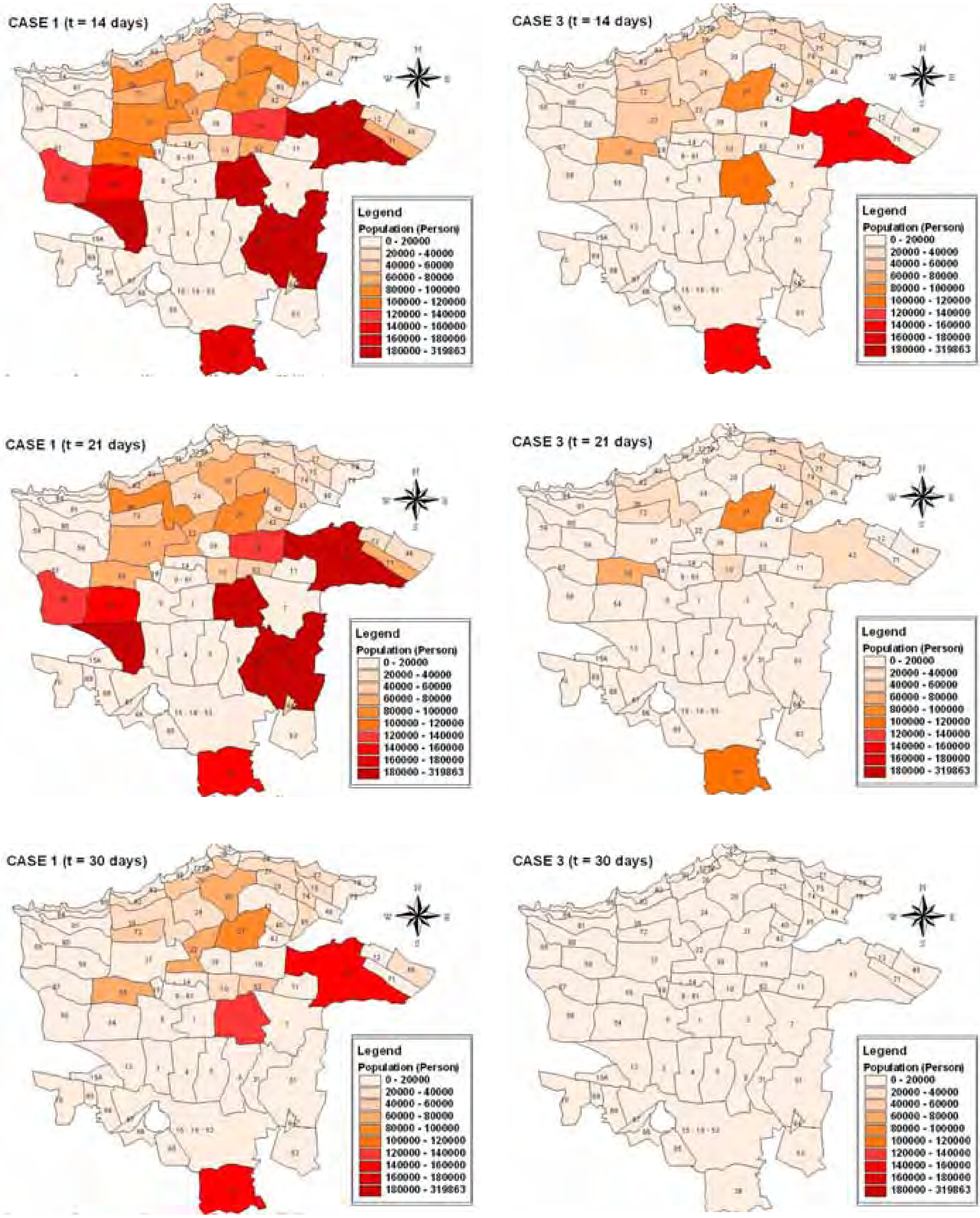


Figure 7.1.9 Water Supply Interrupted Population（t=14 and t=21 and t=30）

3) Pipe Restoration Team

The number of pipe restoration teams in each case is shown in *Table 7.1.12.* In CASE-1, 3,059 teams in total are required among them 82 teams are for transmission mains, 315 teams are for distribution trunk mains, and 2,662 teams are for distribution sub-mains (service connection is included).

Total number of pipe restoration teams decreases in CASE-2, CASE-4, and CASE-5 because the number of damage location is also decreased. In CASE-3, the number of standby team, in other words late start team, has increased because restoration of distribution trunk main should be done from upstream to downstream and simultaneous works cannot be done. The teams are composed of TWWC pipe restoration team and assistant teams from water companies in other provinces and private companies.

Table 7.1.12 The Water Supply Interrupted Population and Required Days for Restoration

No	transmission main (team)	distribution trunk main (team)	other (team)	total manpower (team)
CASE-1	82	315	2,662	3,059
CASE-2	0	175	2,622	2,797
CASE-3	0	232	2,814	3,046
CASE-4	0	9	2,709	2,718
CASE-5	0	9	2,589	2,598

The transition of number of pipe restoration team in each case is shown in *Figure 7.1.10.*

In CASE-1, 21 teams will become standby for one week immediately after the earthquake, i.e. 3 for transmission mains and 18 for distribution trunk mains And then, with the recovery of transmission mains and distribution trunk mains, the number of restoration teams for distribution sub-mains will be increased.

The transition of restoration team depends on its countermeasures in CASE-2-CASE-5. In CASE-2, lots of restoration team can work at one time in wide area since all of the repair works are at downstream of distribution trunk main. As a result, the restoration period in CASE-2 will become shorter than CASE-1. In CASE-4 and CASE-5, restoration period will be shorter than CASE-2, since repair works can be started from distribution sub-mains.

In CASE-3, restoration period becomes shorter than CASE-2 because of double input of restoration teams, which are consisted of TWWC teams and teams of assistants.

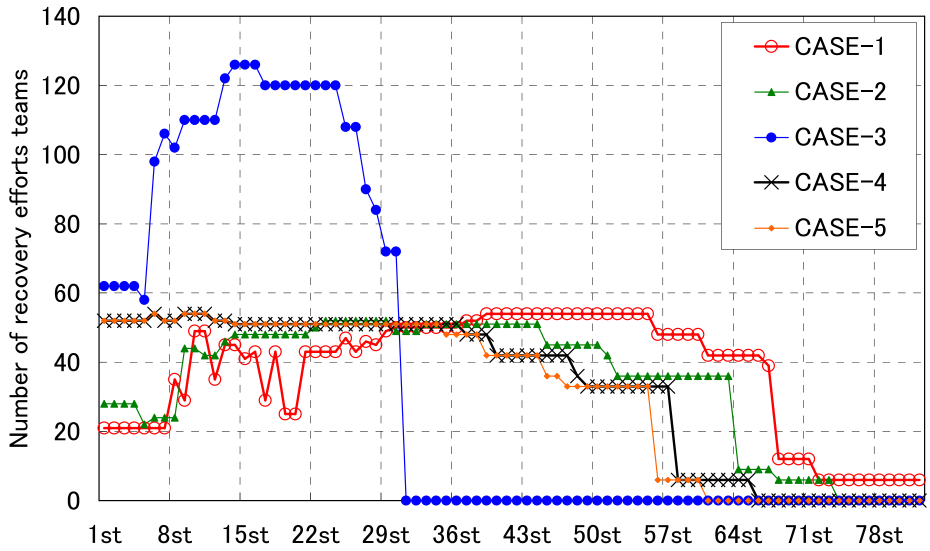


Figure 7.1.10 Numerical Transition of Emergency Restoration Groups

The allocation of emergency restoration teams, used for the simulation, is shown in *Table 7.1.13*. Nine teams are assumed to work from the initial stage in WTP-5 route, which has large damage. The restoration teams, which can finish the repair in short period, are assumed to assist other reservoir zone. These teams are team 1 of District Ⅳ, team1 of team1-team3 and District Ⅵ of team2 and District Ⅴ, and team 4.

Table 7.1.13 Arrangement of Emergency Restoration Team

team no		Arrangement of recovery efforts team						
District Ⅰ	team 1	WTP-5_gravity		(Completion)				
	team 2	WTP-5_gravity		(Completion)				
	team 3	WTP-5_gravity		(Completion)				
District Ⅱ	team 1	WTP-5_gravity		(Completion)				
	team 2	WTP-5_gravity		(Completion)				
	team 3	WTP-5_gravity		(Completion)				
District Ⅲ	team 1	WTP-1_pump		(Completion)				
	team 2	WTP-1_pump		(Completion)				
District Ⅳ	team 1	WTP-3_gravity2	→	WTP-3_gravity1		(Completion)		
	team 2	WTP-3_gravity2	→	WTP-3_gravity1		(Completion)		
	team 3	WTP-5_gravity		(Completion)				
District Ⅴ	team 1	WTP-2_pump2	→	WTP-2_pump1		(Completion)		
	team 2	WTP-2_pump2	→	WTP-2_pump1		(Completion)		
	team 3	WTP-2_pump2	→	WTP-2_gravity1	→	WTP-2_gravity2		(Completion)
District Ⅵ	team 1	WELL_west	→	WELL_east		(Completion)		
	team 2	WTP-5_gravity		(Completion)				
	team 3	WTP-5_gravity		(Completion)				
	team 4	WTP-1_gravity	→	WELL_east		(Completion)		

The restoration works are assumed to be done from transmission main, distribution trunk main, and then distribution sub-main (service connection is included). Restoration of transmission main is from reservoir zone in the upstream to the zone downstream. As an example, the restoration process in transmission main network system in WTP-5 gravity route is shown in *Figure 7.1.11* and *Table 7.1.14.*

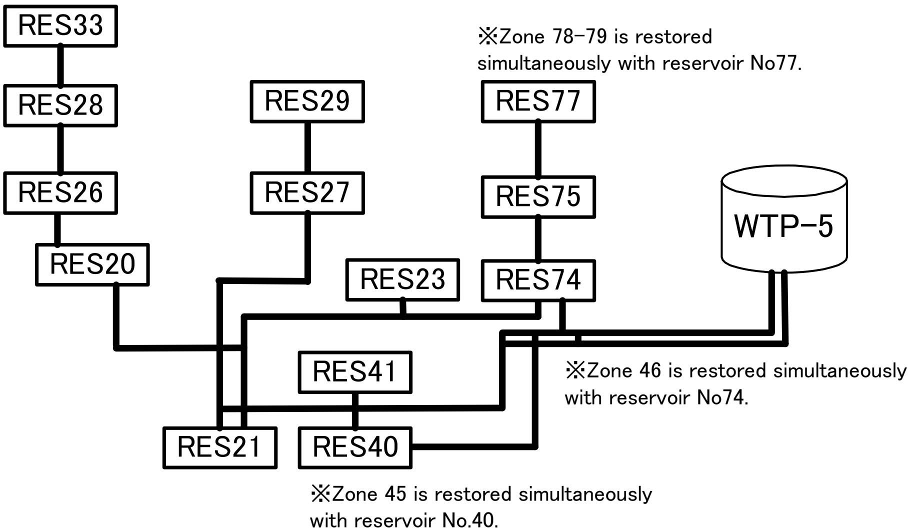


Figure 7.1.11 Transmission Trunk Main Network of WTP-5 Gravity Route

Table 7.1.14 Emergency Restoration Process in CASE-1 and CASE-3

the order of reservoir zone	emergency restoration(CASE-1)							emergency restoration(CASE-3)						
	transmission trunk main (day)	distribution trunk main (day)			distribution sub main (day)			transmission trunk main (day)	distribution trunk main (day)			distribution sub main (day)		
41	0	8	～	9	10 13	～ ～	11 16	0	4	～	4	6	～	8
20	11	12	～	12	16 18 21	～ ～ ～	16 18 31	0	4	～	4	8	～	14
26	14	0	～	0	31	～	39	0	0	～	0	14	～	17
28	16	0	～	0	39	～	46	0	0	～	0	17	～	21
33	16	0	～	0	46	～	47	0	0	～	0	21	～	21
23	16	0	～	0	47	～	51	0	0	～	0	21	～	23
27	16	17	～	17	52	～	57	0	5	～	5	23	～	26
29	18	19	～	19	57	～	58	0	5	～	5	26	～	26
74	18	0	～	0	58	～	58	0	0	～	0	26	～	26
46	18	0	～	0	0	～	0	0	0	～	0	0	～	0
75	18	19	～	19	58	～	59	0	5	～	5	26	～	26
77	18	19	～	19	59	～	59	0	5	～	5	26	～	26
78	18	0	～	0	0	～	0	0	0	～	0	0	～	0
79	18	0	～	0	0	～	0	0	0	～	0	0	～	0
40	18	19	～	19	59	～	61	0	5	～	5	27	～	28
45	18	19	～	20	62	～	63	0	5	～	5	28	～	28
21	18	20	～	20	63	～	67	0	5	～	5	28	～	30

In CASE-1, restoration period of transmission main is 18 days, distribution trunk main is restored on the 20th day, and distribution sub main (service connection is included) is restored on the 67th day.

In CASE-3, distribution trunk main is restored on the 5th day, and distribution sub main (service connection is included) is restored on the 30th day and satisfy the target.

The emergency restoration processes in other transmission main systems are shown in Appendix -9.4.

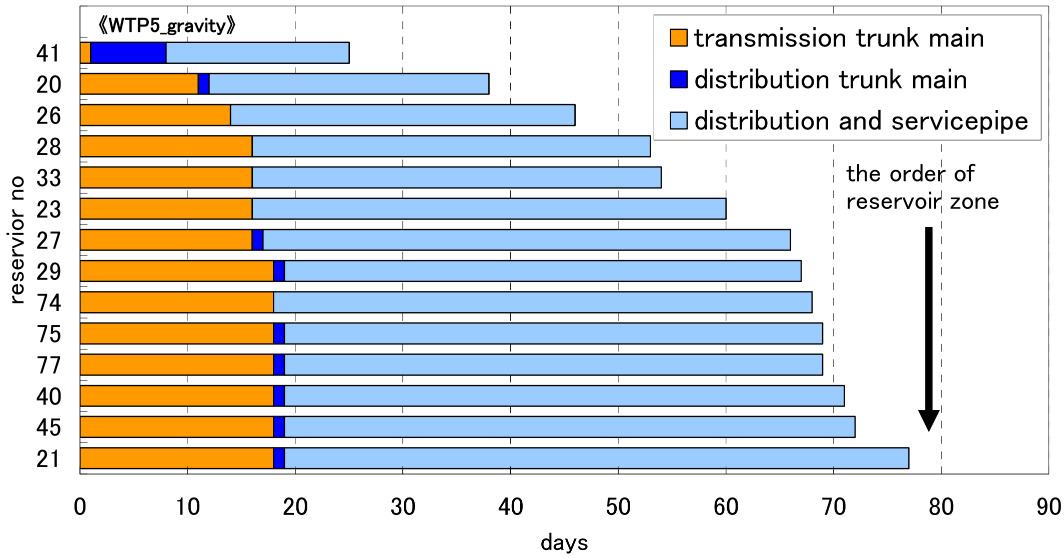


Figure 7.1.12 Emergency Restoration Process in CASE-1

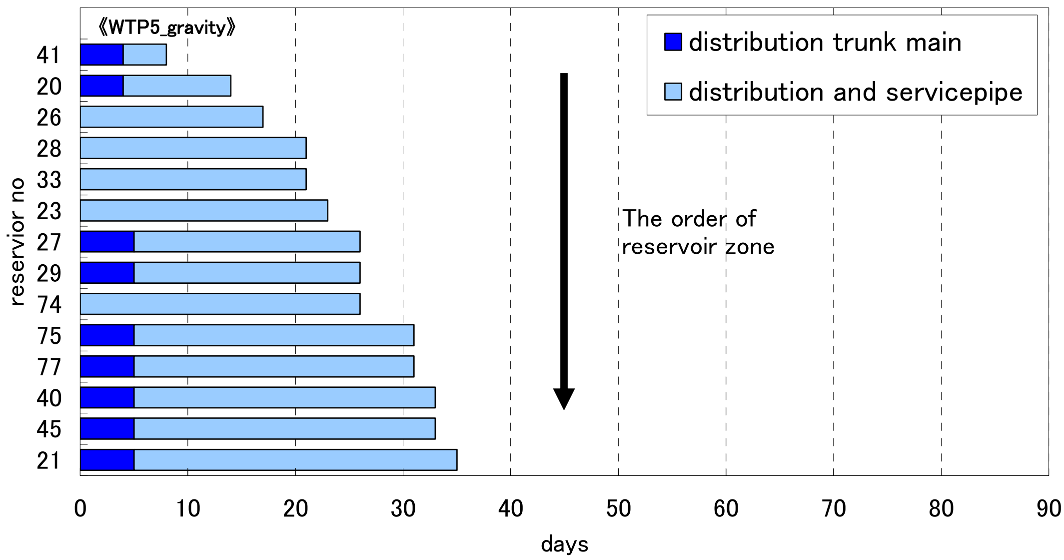


Figure 7.1.13 Emergency Restoration Process in CASE-3

(3) Analysis on Effect of Anti-Earthquake Measures

Anti-earthquake measures can be classified into two, i.e. reinforcement of facilities to be earthquake-proof and the emergency measures. The method of "reinforcement of facilities to be earthquake-proof" is effective to reduce water supply interrupted population, while "the emergency measures" are effective to shorten the emergency restoration period.

Damage on water supply system can be minimized by making all the facilities earthquake-proof. However, the work volume is huge and long period and huge amount of money will be required for its execution. And then it is required to find adequate countermeasures, which consider the balance of facility reinforcement and emergency measures in consideration of budget.

The first step is to understand the quantitative influence of the water supply interrupted population and restoration period to the residents. The next step is to examine the effects of anti-earthquake measures of CASE-2-CASE-5 by using the above influence level found in the first step.

Figure 7.1.14 shows the water supply interrupted population and the restoration period in each case. The difference of the initial water supply interruption population in CASE-1 and CASE-2-CASE-5 is mainly due to effects of restoration of transmission mains. The difference of restoration period in CASE-2 and CASE-3 is due to an effect of the increase of emergency restoration team. In CASE-3, the target for the restoration period of one month can be achieved.

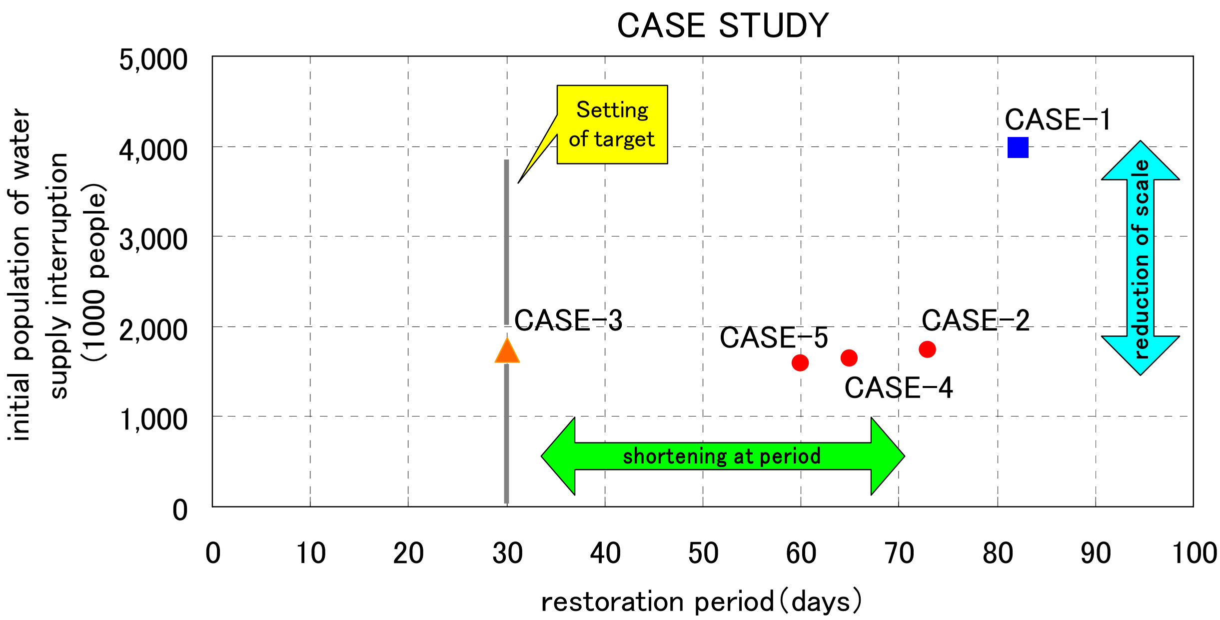


Figure 7.1.14 Water Supply Interrupted Population and Restoration Period in each Case

The results of the simulation in each case are shown in *Table 7.1.15.*

- Restoration of Transmission Main: （CASE-2） － （CASE-1）

The effects of the measures are that initial water supply interrupted population is decreased by 2,250 thousand persons, emergency restoration period is shortened by 9 days, and accumulated interrupted population is decreased by 61,290 thousand persons.

-Measures at Active Faults in Distribution Trunk Mains: （CASE-4） － （CASE-2）

The effects of the measures are that initial water supply interrupted population is decreased by 100 thousand persons, emergency restoration period is shortened by 8 days, and accumulated interrupted population is decreased by 16,100 thousand persons.

- Measures at Active Faults in Distribution Trunk Mains and Distribution Sub-mains. : （CASE-5） － （CASE-4）

The effects of the measures are that initial water supply interrupted population is decreased by 50 thousand persons, emergency restoration period is shortened by 5 days, and accumulated interrupted population is decreased by 3,370 thousand persons.

- Increase of number of Emergency Restoration Team: CASE-3） － （CASE-2）

The effects of the measures are that emergency restoration period is shortened by 43 days, and accumulated interrupted population is decreased by 34,750 thousand persons.

Table 7.1.15 Results of the Simulation in Each Case

No	initial population of the water supply interruption (1000 people)	the required days for restoration (day)	total the water supply interrupted population (1000 people)
CASE-1	3,990	82	125,770
CASE-2	1,740	73	64,480
CASE-3	1,740	30	29,730
CASE-4	1,640	65	48,380
CASE-5	1,590	60	45,010

When CASE-2, CASE-4, and CASE-5 are seen, it is difficult to achieve the target of making to earthquake-proof only because of making earthquake-proof.

Therefore, it is necessary to consider the balance of the reduction of the damage scale and for shortening the restoration period like CASE-3.

The target of making earthquake-proof can be achieved by executing making of transmission main and distribution trunk main earthquake-proof (6.2 references), and doubling the recovery efforts team.

When transmission main and distribution trunk main earthquake-proof measures are executed, it is required to examine the priority and the balance of “the amount of facility reinforcement works” and “the number of recovery teams” in consideration of budget.

The simulation is the results of analysis assuming the damage in transmission main, distribution trunk main, distribution sub-main and service connection only. When damages on power plant and raw water transmission main, and water treatment plant are considered, each restoration period and the water supply interrupted population must be added to the result of the simulation.

7.2 Common Countermeasures for Emergency Water Supply and Restoration

It is indispensable to make clear the organization for emergency countermeasures in order to take proper actions after earthquake disaster. Arrangement of assistants from other organizations and reinforcement of information system are also very important for execution of emergency water supply and for expediting repair of water supply system after earthquake. This section explains the important countermeasures which are common to emergency water supply and restoration.

7.2.1 Organization and Initial Activities of Emergency Countermeasures

Initial activities can be started smoothly when organization and the duties of each division are clearly understood by all the staffs. Proposed organization after the disaster and the duties are presented herein, and then initial activities to be taken are discussed. Mobilization of the staffs and education / training of the staffs are also important issue for the initial activities.

(1) Organization and Duties (TWWC)

The organization chart of crisis management commanding and its duty description for the head of each division are prepared by TWWC. Based on this information, organization chart for crisis management and the major duties of each section are summarized in *Figure 7.2.1* and *Table 7.2.1* respectively.

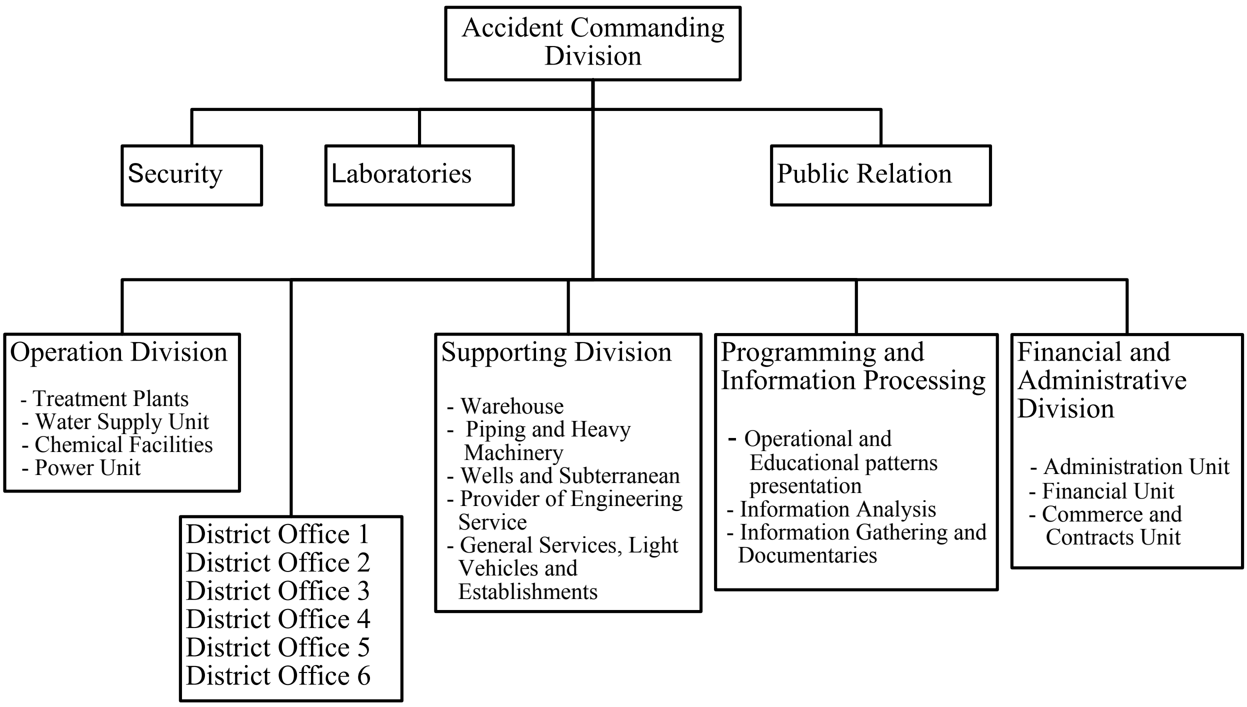


Figure 7.2.1 Organization for Crisis Management in TWWC

Table 7.2.1 Duty Description of Each Section in Emergency

Unit in the Organization	Duty Description
Accident Commanding Office	- Command to all sections of TWWC - *Coordination with and request assistance through TDMO* - *Requesting for assistance from private companies* - *Giving required information toTDMO, government, assistants and mass communication* - *Coordination with other organization than TWWC such as military, police, other water companies, private companies and volunteers*
Security	- Management and coordination of security affairs
Laboratories	- Quality control of water to be supplied
Public Relation	- *PR on limited usage of water, location of emergency water supply base* - *Assistance for emergency water supply*
Operation Division	- Giving /Collection of Information to/from all related offices. (WTP, pumping station and water transmission) - Preparation of data for deciding countermeasures by the Commanding Office - Safety measures of sites
Water Treatment Plant	- Utilization of water treatment plant
Water Supply Unit	- Arrangement / restoration of water transmission - Control of Reservoir storage / pumping station - *Allocation of restoration team and other assistant team* - *Instruction of Emergency Water Supply to TWWC staffs and assistants*
Chemical Facilities	- Safety keeping of chemicals such as chlorine
Power Unit	- Repair of electrical equipment and management of power
Water District Office 1, 2, 3, 4, 5, 6	*Emergency Repair of Distribution System* - *Security of work sites* - *Checking the networks and reporting* - *Communication with road authorities etc* - *Adjustment of water supply* - *Repair of distribution pipes* - *Restoration of house connections* - *Preparation for assistance to works*
Supporting Division	
Storehouse unit	- Transport required goods for crisis management
Piping & heavy machinery	- Giving pipe and heavy machinery - Ordering required pipes to suppliers
Wells and Subterranean	- Provide information and service of spare subterranean water resources
Backup and engineering services	- Preparation of technical information and making technical reports
Light Vehicle and General Services	- Transportation of personnel and repair of telecommunication
Division of Programming and Information Processing	-Coordination of communication methods when telephone cannot be used -Communication with facilities which lost communication methods

Operational & Educational Patterns Presentation Information Analysis	- Management of documentary, comprehensive quality management and education of elected individual for crisis - Preliminary analysis of needs /problems and determining the solution.
Data Processing Unit	- Collection / confirmation of information on damage level and reporting - Preparation of data for deciding countermeasures by commanding office
Financial –Administrative Division	- *Arrangement of assistance of manpower for Emergency water supply, reinforcement of important facilities, helpers from other cities, public relation to helpers and others.* - Cash payment and receiving
Financial Unit	- Other necessary actions in financial field - *Collection of information of staff gathering status*
Administration Unit	- *Receiving of Assistants from other organizations* - *Supply of required food and clothes* - *Preparation of accommodation and beddings* - *Preparation of medical affairs*
Commerce & Contract Unit	- Preparation and supply of goods and services

Note : Duties written in Italic are recommended by the Study Team since they are not mentioned in task description prepared by TWWC.

Proposed duties, related to emergency water supply and restoration, are further described in Section 7.3.2 and Section 7.4.2 respectively.

(2) Initial Activities

It is important for Accident Commanding Division to be set up within 24 hours after an earthquake disaster in order to get the information of the damage level, to control the required activities of TWWC and to coordinate with other organizations outside TWWC without delay.

Several activities should be done with limited number of staff just after the earthquake. When initial activities are well organized, it will lead the smooth implementation of emergency activities. Major items of initial activities, before proper setting up of organization for crisis management, are summarized below.

- Confirmation of staff numbers
- Task allocation to the leader and other staff
- Initial investigation of damage and emergency measures
- Initial collection of information and recording
- Emergency measures for prevention of secondary disaster
- Other urgent activities required

And then, the following initial activities should be continued.

- To set up organization of crisis management
- To transfer commands from the Accident Commanding Office

- To check the level of damage on water supply system
- To request for assistants from other organization
- To request private companies for water tankers, heavy vehicles and others.
- To order pipe material and others in short
- To check possibility of secondary disaster
- To check water treatment plants, pumps and other important facilities
- To check the staffs gathered
- To record damage information obtained from gathered staff and others
- To start emergency water supply
- To survey water transmission lines
- To survey distribution lines
- To set up emergency restoration head office and to set target of restoration
- To prepare leak detection and restoration plan by deciding priority
- To start leak detection and repair

(3) Mobilization of Staff after Disaster

Smooth / quick mobilization of staffs is indispensable for stating emergency activities without delay. Following should be decided beforehand to expedite the mobilization after accidents.

1) Rules for coming to office:

Rules for staff's gathering after earthquake disaster should be decided and be clearly understood by all the staffs. After a certain level of earthquake all the staff should come to designated offices of TWWC.

2) The places to gather by each staff:

The location for each staff to gather should be decided beforehand, taking into account of the skills, its assignment sections, and address of the residence. Lists of the staff to be gathered at each place should be prepared and reviewed periodically for attendants to be checked without confusion. It is desirable to store required material and equipment for the activities at the gathering places.

3) Tentative places:

If the staff can not reach to the designated place, he or she should go to the nearest place and its leader should report to Financial and Administrative Division, which will arrange manpower, and follow the instruction. If it is reasonable, the staff will be transferred to the originally designated place.

4) Notes for the staff to gather:

Notes for the staff to gather should be prepared and understood by all the staff, which will include:

- Clothes should be selected considering safety and easy actions/movement
- Minimum belonging should be brought
- The staff should collect data of the damage along the way to the gathering places and repot it to the leader in the site.

5) Leader:

Leader of the gathering place should be selected beforehand. If the selected leader cannot come, the highest ranking staff should act as the leader. Duty of the leader and the other staffs should also be decided beforehand.

6) Recommendation for Expedition of Staff Gathering

TWWC staff faces following difficulties in quick gathering at the ordinal working places.

- The residential area is far from the work site.
- They cannot gather before confirmation of safety of family especially when they should leave the family in a far away distance.
- Mobilization will be difficult and the situation will become worse in the night or holiday.

It is not reasonable to change working sites of such key staffs as skilled persons for pipe restoration. They should execute emergency restoration works at the accustomed places after earthquake disaster. Considering the difficulty, following methods are recommended for expediting mobilization of the key staffs.

- Preparation and rental of accommodations to key staffs of restoration in the same water district. These key staffs should work for the initial activities.
- Re-arrangement of ordinal working sites for some repair staffs to the nearest water district from their resident.
- Providing motor bikes to key staffs of restoration for quick mobilization after earthquake. These key staffs should collect information of damage at the sites by using the motor bikes and then report to the leader.

(4) Education and Training of Staff

Education and training of staffs are indispensable for smooth implementation of initial activities. It is important for TWWC staffs to improve judgment capacity after a crisis together with knowledge and technical skills of crisis management through training and seminar. The training item should include basic knowledge of earthquake, estimated damage after earthquake, organization of crisis management, and rescue operation. It is also necessary for crisis management that all the staffs have good understanding of their duties and rolls during disaster management. TWWC knows its importance and is executing several maneuvers to improve the skills and conscious mind of staff

It is also important for assistants from other sections and outside to work without confusion. The skills of controlling several groups should also be improved through maneuvers and discussions among the staffs.

The following maneuvers are recommended to be conducted periodically:

- Maneuver for MOBILIZATION should be done for establishment of "staff mobilization system" by confirming the gathering places and understanding duties and initial activities.

- Maneuver for COMMUNICATION should be done to establish emergency communication system. Efficiency of all the communication should be checked. It is required to confirm that the commanded matter is well understood by all the members. The command should be given concisely and clearly in order to avoid confusion and misunderstanding. Communication skills are required to be improved through maneuver.
- Maneuver for CHECKING FACILITIES should be done to check safety measures, movement of major valves and condition of emergency equipment such as generator.
- Maneuver for EMERGENCY WATER SUPPLY should be done to confirm locations of emergency water supply bases, condition of water tankers, installation of temporary water tanks and temporary service taps, pumping up of groundwater by using generators, chlorination, checking of residual chlorine, and usage of other equipment.
- Maneuver for Emergency Restoration should be done to try temporary exposed piping, cutting and installation of pipes.
- Other Maneuvers are also required for simulation of water suspension and simulation on several arrangement of water transmission by changing direction.

7.2.2 Assistance from other Organizations (Relation with other Organizations)

Figure 7.2.2 shows the methods of calling assistance from other organization to TWWC.

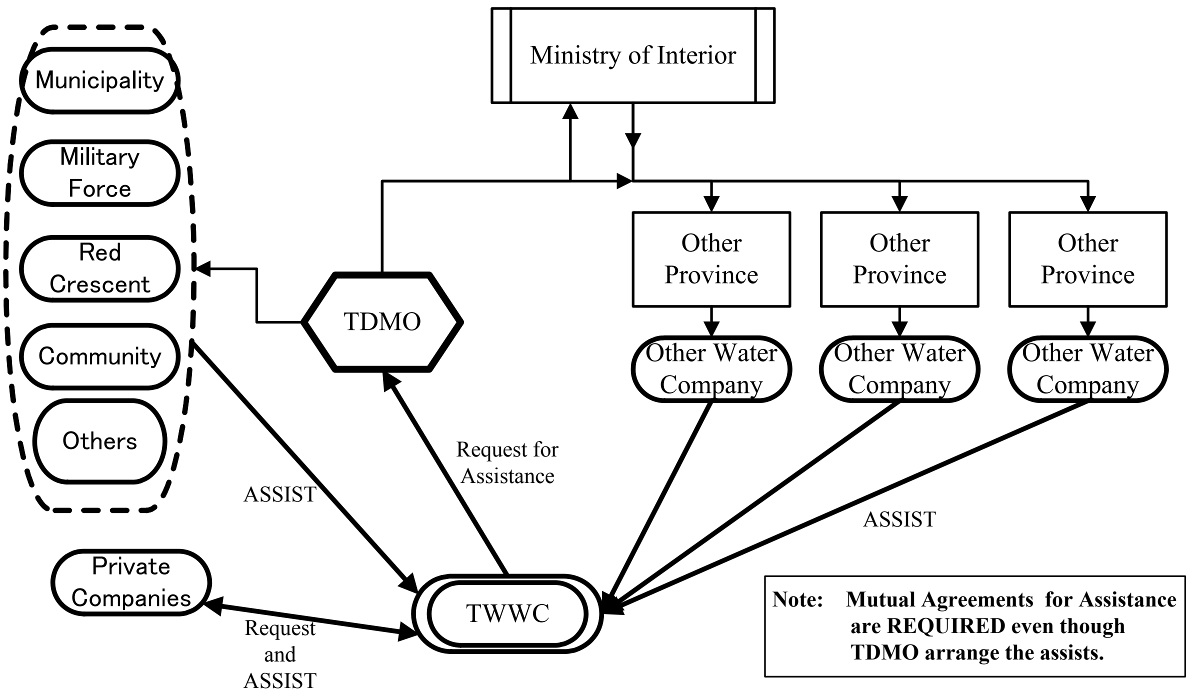


Figure 7.2.2 Assistance from Other Organization

(1) Tehran Disaster Management Organization (TDMO)

After earthquake disaster, a committee named "Disaster Management Task Force" is to be established to manage crisis in Tehran Disaster Management Organization (TDMO). The Mayor of Tehran will chair the Task Force, which consists of representatives of more than thirty organizations such as military, Red Crescent, fire fighting organization, police and infrastructure such as TWWC, gas company and electricity company as described in JICA Master Plan. The Task Force will decide the required mutual cooperation among the members and communicate with government offices.

TDMO is expected to assist emergency activities of TWWC in several ways, which include following:

1) Required information

TWWC should gather information of damage by earthquake on other infrastructures such as electricity, gas and traffic. Information on estimated restoration period of them is also useful. On the contrary TWWC should give information of damage on water supply system in order to ask for assistants from other organizations through coordination of TDMO. Information of water outage areas, places of emergency water supply, and anticipated restoration period should be given to TDMO in order to minimize the affects of the damage. The other organizations can get / give information of damage on water supply system through TDMO.

2) Assistance for emergency activities of TWWC

It is required to coordinate with municipality, military force, Red Crescent and community for emergency water supply with assistance of TDMO before earthquake. Since it is difficult for Red Crescent to assist in all areas of Tehran, municipality or communities are expected to perform key roles. It is also required to coordinate with TDMO in preparation of a plan for emergency water supply to important water supply bases, such as evacuation places and hospitals.

3) Training of residents

TDMO is executing pilot project for emergency evacuation and training to community for emergency activities. TWWC is recommended to join TDMO's program to educate / train community people. The consumers should be educated on storing drinking water and keeping it good quality. Volunteers for emergency water supply are expected to be selected and trained.

4) Coordination with Police and Road Authorities

Coordination with police and road authorities is indispensable for emergency measures of TWWC through arrangement by TDMO. TWWC should obtain several permissions, which include following:

- Emergency traffic pass
- Emergency water supply from fire hydrant (Disturbance of traffic)
- Pipe restoration
- Road restoration after the works

Coordination with other owners of buried pipes and other organization's restoration works will become important and should be arranged through TDMO.

(2) Assistance from Other Water Companies

Ministry of Interior has directed each province to assist Tehran when earthquake causes damage and other water companies are ready to come to Tehran for assisting TWWC. The required procedure after earthquake is that TWWC request TDMO, which will request each province to dispatch assistant team of another water company to TWWWC as shown in *Figure 7.2.2*. While TWWC should also become an assisting company when other water companies suffer from disaster, other companies' support to TWWC is mainly discussed in this report.

1) Agreements with Other Water Companies

Since understanding of detailed cooperation between TWWC and other water companies has not been decided, it is not known the number of teams or skills of the teams to assist TWWC. TWWC is now making efforts to have good relation with other water companies and then to start discussion. It is important to have meetings among water companies to discuss about disaster management and then to make mutual agreements between TWWC and other water companies. The agreements should describe assistant components, such as number of team, available pipe material, tools and equipment, duration of assistance and responsibility of cost. TWWC will be required to ask other companies to prepare a list of such availability for assistance to TWWC after earthquake as number of teams, tools and equipment, and the maximum period of assistance.

It is very important to have periodical discussion with these water companies to confirm / review the agreement and to exchange information of activities, which include improvement of stocked materials, pipeline drawings, and manuals. Exchange of idea on emergency activities is also important.

2) Expected Assistant Teams

The standard team component will be as follow.

- Team for emergency water supply: Standard members of each group are three in number, composed of a driver and two staff for water supply. Each group should have a water taker, loudspeaker, lighting equipment and safety equipment.
- Team for leak detection: Standard members of each group are four in number, composed of one leader and three workers. Each group should have tools and equipment for leak detection.
- Team for emergency restoration: Standard members of each group are eight in number, composed of one leader, one for recoding and six workers. Each group should have tools and equipment for repair.

3) Responsibility of Cost

It is required for TWWC to discuss with other water companies and to decide assistance period and the responsibility on detailed cost before earthquake. The duration of dispatched duty for each group will be about one to two weeks considering the importance of continuity and staff's health. The replacement of the groups should also be considered.

It might be reasonable if cost for manpower and vehicles are beard by the other companies, because they spend the cost even when they do not assist. The other expenditure, such as accommodation and material, will be paid by TWWC or subsidy to TWWC. This cost allocation is recommended based on experience of Japanese waterworks, which is shown in *Table 7.2.2*.

Table 7.2.2 The Idea of Cost Allocation in Japan

Items	Paid by the damaged Water Companies	Beard by Assistant Water Companies
Personnel Expenses	Allowance for overtime, travel expenses and the others	Salary and basic allowance, which will be paid in ordinal conditions
Materials	Cost for pipe materials	
Contract Works	Cost for contract works	
Vehicles and tools	Fuel (gasoline, oil), Repair, Rental charge, Mobilization	Vehicles and Tools brought by assistants
Cost for Stay	Foods and Lodging	Foods, tents and clothes brought by assistants
Other Expenditure	Photo for the works, supply expenses for works, communication. Emergency treatment pay for wounds Compensation for damages (during the assistant works)	Photo for assistant's usage. Other stationeries. Other treatment pay for wounds Compensation for damages (during mobilization and demobilization)

4) Expected Tools and Equipment to be brought

The other water companies are expected to bring the following for emergency water supply:

- Water tankers, which requires permit for emergency pass
- Loudspeakers
- Flashlight and lighting equipment
- Safety equipment
- Engine pump for emergency water supply
- Submersible pump and Horse made of clothes
- Fuel tank
- Temporary water supply tank
- Emergency water supply taps
- Measuring instrument for residual chlorine
- Mobile phone

It is desirable for other water companies to bring following for emergency restoration:

- Vehicles such as crane truck and emergency motor vehicles, which requires permit for emergency pass
- Tools for leak detection such as acoustic rod, electronic leak detector, micro correlator, pipe locator, measure, and pressure gauge
- Tools for pipe jointing (for PVC, PE, SP and DCIP)
- Tools for pipe cutting such as cutter, drill, and code reel
- Tools for earth work such as drill, hand breaker, pickax, concrete cutter, compactor, and compressor
- Tools for drainage such as submersible pump, generator, and cloth hose
- Safety equipment such as signboard, barricade, cone, and lamps
- Tools for valve operation such as operation key
- Tools for water quality test such as residual chlorine meter
- Other tools such as mobile phone, flush light, and camera.

It is useful to know the stock of tools, equipment and pipe materials by other water companies. An example of inquiry form for stored tools and equipment by each water company is shown in *Table 7.2.3*.

Table 7.2.3 Inquiry Form of Stored Tools and Equipment by Other Water Companies

List of Stored Tools and Equipment

Name of Water Company:

Date:

Item	Description	Number owned	Available number for Assistance	Remarks
Vehicle	Water Tanker (m^3)			
	Water Tanker (m^3)			
	Truck			
	Crane Truck			
	Others			
Tank	Potable tank(m^3)			
	Potable tank(m^3)			
	Potable tank(m^3)			
	Supply bag (?)			
	Supply bag (?)			
	Supply bag (?)			
	Others			
Other Tools	Emergency Taps			
	Portable filter			
	Generator (kVA)			
	Generator (kVA)			
	Flood light projector			
	Pipe Cutter (mm)			
	Pipe Cutter (mm)			
	Threading machine			
	Others			
Straight Pipe*				
Fittings**				

Note: Straight Pipe*: Please show pipe material and diameter
Fittings** : Please show pipe material, diameter and type of fitting

If other water companies are not accustomed to pipe materials used in Tehran such as DCIP, training should be given to their repair teams. Uniformity of material standard with other cities should be considered.

(3) Assistance from Private Companies

Since private companies will become a great help after earthquake, it is useful to have direct discussion with several private companies and make agreements if possible. Agreements with private companies will include the following items

- Items regarding the Contract
- Delivery period of goods and contents of work

- Emergency Contact system/organization
- Other specific items regarding to cooperation

It is required to revise prepared list of companies periodically

The required arrangements on assistance from private companies include following.

1) Emergency Supply of Pipe and Other Material

TWWC has stock of pipes and other materials for repair but it is not economical to retain all kinds of pipe materials, and difficult to keep space especially for large sized pipes. TWWC should have agreements with supplier or manufacturer for emergency supply after earthquake in addition to get information on their stock and the capability of production / supply.

2) Emergency Restoration

Private companies can be expected to execute emergency repair of pipes after earthquake if they are accustomed to pipe installation / leakage repair works during ordinary times.

In many water districts it is not usual to use private companies for pipe installation and repair. It is required to make a system of training to private companies and issue certificate for them after their skills reached to a certain level. And then such private companies should be used for pipe installation and repair in normal condition. Such activities are started in some water districts and should be encouraged in the other water districts.

3) Heavy Vehicles

Several private companies have heavy vehicles and it will be helpful if they can be used after earthquake. It is required to make a list of these companies for emergency assistance. If TWWC makes agreements with these private companies on usage of such vehicles, sufficient number of heavy vehicles will contribute smooth and easier emergency activities after earthquake.

4) Water Tanker

Municipality is now using lots of private takers for irrigation or watering the green area. These water tankers will be useful for emergency water supply if private companies agree. TWWC is expected to prepare a list of these private companies together with the number and the capacity of water tankers. It is desirable for TWWC to reach agreements with these companies for emergency hiring after discussion with Municipality.

(4) TWWC's Preparation for Receiving Assistants

TWWC is required to prepare organization and manual for receiving assistance beforehand in order to start / execute smooth and quick emergency activities. While the organization and manuals should be revised at least once a year, the key duties of each organization are summarized below:

- To inform gathering location by Commanding Division
- To allocate suitable works by Water Supply Unit in Operation Division
- To guide to sites or inside the locations by each Emergency Posts
- To prepare pipeline drawings by each Water District
- To prepare adjustment equipment for different standards by Backup Division
- To prepare accommodation, parking and foods by Administrative Office

It is required to prepare several plans before the disaster such as:

- Plan on preparation of base camp, lodging and meal service to the assistants
- Plan on acquisition and supply of emergency necessities to the assistants
- Plan on stock and supply of required equipment for assistant activities
- Plan on staff allocation for conductor and guide to assistant groups
- Plan on allocation of work and duties to the assistant
- Plan on circulation of information to assistants

Following shows the required drawing to be prepared.

- General Map of distribution area to show emergency water supply bases and points, hospitals, schools and other important facilities.
- Distribution pipe drawings with about 1/25000 scale, which shows pipe route, diameter, pipe material, location of valves, and fire hydrants.
- House connection drawings with about 1/500 scale, which shows pipe material, diameter, house, meter and taps.
- Drawings of water treatment plants, reservoirs and other facilities. Ledgers, which show open-close condition of valves, should also be prepared.
- Road route maps, which show important facilities and emergency road.
- Location map of material stock yards and waste disposal area.

The drawings should be kept in several locations in order to take quick action after earthquake disaster and pipe drawings should be updated at least once a year.

7.2.3 Preparation of Manual

It is useful to prepare manual for the emergency activities in order to take adequate and quick action after earthquake disaster. TWWC should prepare manuals for emergency activities, which explain emergency water supply activities, plan of emergency restoration, communication system after disaster, agreements with other water companies and private companies, accepting teams of assistants, and commanding system to assistant teams. It is important to make all the staff of TWWC understand the manuals, and periodical execution of maneuvers following the prepared manual will useful for the purposes.

The manuals to be prepared are explained below.

(1) Manual for Initial Activities

The manual should describe following:

- Target of emergency water supply and restoration
- Organization chart for emergency countermeasures and duty description of each division
- Organization and member of each divisions and sections
- Rules for staff gathering

- Gathering locations and allocation of staffs
- Collection of information and estimation of damage level
- Securing of internal communication
- PR activities
- Securing of required tools, materials and equipment
- Request for assistants (List of contact places such as other water companies and private companies)
- Acceptance of assistants

(2) Manual for Emergency Water Supply

It is required for TWWC to prepare manuals for emergency water supply, which will be very useful for activities by the assistants. If preparation for acceptance of assistants is insufficient, it will not be easy for TWWC to give smooth and proper orders to assistants after earthquake disaster. It will be also difficult for the assistants to take quick and adequate actions since they are not familiar with the sites and water supply system of TWWC. Therefore the manuals to be prepared by TWWC should include following:

- Methods of emergency water supply, which includes required tools & equipment together with allocation of TWWC staff and assistants for emergency water supply. The allocated locations are emergency water supply bases, water tankers including direct supply from water tanker, temporary tanks, and temporary water supply taps connected to fire hydrant.
- Location of water supply facilities, which are indicated in general map, pipeline drawings and road maps. The location of emergency water supply bases and of fire hydrant to be used for emergency water supply should also be indicated.
- Location of important facilities such as evacuation places, general hospitals and welfare facilities. These locations should be listed up and indicated in pipeline drawings and road maps.
- List of water tankers to be requested. Owner of water tankers should be checked and listed up. It is important to make previous discussion and arrangement with them.
- The communication methods with assistants. TWWC should select and make clear the staffs in charge of the communication. Improvement of communication among each assistant group should also be considered.

(3) Manual for Reporting of Emergency Water Supply Activities

It is important to know the activities executed and to record the requirements and the results. Therefore TWWC should prepare manual for uniformed reporting of the activities, which will be used by teams of TWWC and assistants. The reports should be concise and in written form, which can be filled in short period. It is necessary to include availability of assistants, activities ordered by TWWC and the results of the activities.

1) Reports on Availability of Assistants for Emergency Water Supply

The report should consist of available number of staff, water supply methods, number of vehicles, and working period. It should be submitted to TWWC one day before staring the activities. A sample format is shown below.

Table 7.2.4 Sample Form of Reports on Available Assistants

Report on Availability of Assistants

Date:

Name of Water Company:

Number of member	Methods of assistants	Number of vehicles	Working Hour
	Convey water to temporary tanks	Units (m^3)	From To
	Direct water supply from water tanker	Units (m^3)	From To
	Distribution of Water Container	Units	From To
	Assistance to Water Supply	Units	From To
Total		Total Units	

2) Reports on Activities Ordered by TWWC and the Results

Both reports of activities ordered by TWWC and of its results will be used as a basic data for selection of activities to be reinforced and for review of team organization. It is better to combine both reports into one. A sample format is shown below.

Table 7.2.5 Sample Form of Reports on Orders by TWWC and Activity Results

Order by TWWC and Results of the Activities

Order by TWWC

Date

Name of Water Company	Number of Member	Vehicle	Method of Assistants	Working Hour
				from to
Remarks				

Results of the Activities

		A	B	C
Location of emergency supply				
Working Hour and Supply volume	1	from to m3	from to m3	from to m3
	2	from to m3	from to m3	from to m3
	3	from to m3	from to m3	from to m3
	4	from to m3	from to m3	from to m3
	5	from to m3	from to m3	from to m3
Number of members			Methods of assistants	Convey to tanks Direct supply Water container Assistance of supply
Working Hour		from to		
Supplied population			Total supply volume	m3
Water feeding points and frequency		WTP, Reservoir, Wells, others times		
Comments				

(4) Manual for Emergency Restoration

It is required for TWWC to prepare manuals for emergency restoration, which will be useful for quick and adequate actions especially activities by the assistants. The manual should include following:

- Basic specification and standard, which include structure of facilities and open / close direction of valves.
- Stored places of drawings and other important documents. These documents should be stored in several locations.
- Methods of emergency restoration. It is necessary to decide methods, such as whether damaged pipes should be repaired or temporary pipes should be installed, before dispatching repair teams.
- Team formation for repair works. Manual should show typical formation, which consists of a leader, persons in charge of valve operation to fill water into pipes, leak detection members, repair technicians and workers.
- Public relation activities to obtain understanding and cooperation on restoration works from the residents. It is important to establish a system for repair teams to convey complain and demands from consumers to head office when they cannot be settled at the sites.
- Selection of priority routes, which should be indicated in pipeline drawings. Transmission pipes, distribution main pipes are the priority routes. The routes to important facilities such as evacuation places, general hospitals and welfare facilities should also be indicated.
- The order of emergency restoration. Restoration works should be principally executed from upstream to downstream. And then, priority routes should be restored in early stage.
- The location of stock yard and waste soil disposal, which should be indicated in drawings. The storage of materials should be controlled in proper manner.
- List of private companies, which can support the restoration works, leak detection works, supply heavy vehicles, supply of materials, and / or supply of fuels.
- Photos of restoration. Photo of original situation, excavation, before and after repair, backfilling, road restoration and final condition at each site should be taken and attached to the reports. The information board is required for photos to show the name of works, slip number, location, date, name of person in charge, and sketch of repaired materials.
- The communication methods with assistants. TWWC should select and make clear the staffs in charge. Improvement of communication among each assistant group should also be considered.

(5) Manual for Reporting of Emergency Restoration Activities

Records of emergency restoration should be compiled since they will become the basic data for permanent restoration, amendment of pipeline drawings, cost allocation, and others. Since it is better to use the uniform format, it is necessary to prepare manual for uniformed reporting of the activities. Emergency restoration groups should submit the reports in the next day of the activities and retain the copy.

1) Reports on Condition of Damage and Repair

The reports should be prepared for each location and include condition of pipe installation, sketch of damaged location and materials used for repair. A sample format is shown below.

Table 7.2.6 Sample Form of Reports on Damage Condition and Repair Works

Reports on Condition of Damage and Repair

Name of Water Company or office:
Repair Date:

<table>
<tr><td>Location</td><td colspan="6"></td></tr>
<tr><td>Earth condition</td><td>Depth</td><td>m</td><td>Soil</td><td>sand, sandy, sticky, others</td><td>Ground water</td><td>Exist, Not exist</td></tr>
<tr><td rowspan="2">Pipe</td><td>diameter</td><td>mm</td><td>Pipe material</td><td>DIP, CI, SP, PC, PE, others</td><td>Installed Year</td><td></td></tr>
<tr><td>Type of connection</td><td colspan="2">Push-on, welding, flange, others</td><td>Pipe Apparatus</td><td colspan="2">Fire hydrant, Air valve, sluice valve, others</td></tr>
<tr><td rowspan="3">Damage</td><td>Road</td><td colspan="5">cave-in, upheaval, split, others( )</td></tr>
<tr><td>Road</td><td colspan="5">vertical, horizontal, bend, break, others( )</td></tr>
<tr><td>Connection</td><td colspan="5">removal, displacement, split, rubber ring(split, displacement) others( )</td></tr>
<tr><td colspan="4">Location Map</td><td colspan="3" rowspan="2">Excavation, Section
(Pavement cm, road bed cm)</td></tr>
<tr><td colspan="4">Pipe drawing</td></tr>
<tr><td rowspan="6">Material used</td><td colspan="2">Description</td><td>Number</td><td colspan="2">Description</td><td>Number</td></tr>
<tr><td colspan="2"></td><td></td><td colspan="2"></td><td></td></tr>
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</table>

2) Records of Restoration of Pipe Breakage etc.

Reports on record of restoration of pipe breakage should be prepared for each location. They should include explanation of accidents, repaired manpower, restoration period, machinery and sketch. A sample format is shown below.

Table 7.2.7 Sample Form of Records of Restoration of Pipe Breakage and Others

Records of Restoration of Pipe Breakage etc

Date		Location		
Damage		Contractor		
Supervisor		Checked	C	
Arrival time		by	T	
Completion time		Work period		

C: contractor, T: TWWC

Explanation	Size etc	unit	number	Sketch (Plan)
Excavator	m^3	h		
	m^3	h		
Dump Truck	11 t	h		
	4 t	h		
	2 t	h		
pump		type		
Worker		pers.		
		h		
Traffic control		pers.		
Conc. breaker				
Driver		h		
Comments				Excavated depth m

In addition to above, blank sketch sheet should be prepared for drawing of repair methods. The information of date, repair number, and location should be filled in the sketch sheet.

(6) Manual for Application of Emergency Traffic Pass

TWWC should obtain emergency traffic pass for required vehicles, which include the cars brought or owned by assistants in addition to the possession of TWWC. It is necessary for TWWC to discuss with polices and then to prepare the required procedures as a manual.

Since it will be required for assistants to arrange permission of traffic up to Tehran when they bring vehicles, previous discussion with the water companies in other provinces on the matter will be required.

(7) Manual for Communication

After earthquake disaster ordinal communication system will be damaged and it will be required to rely on wireless communication system. TWWC is required to prepare manual for handling of emergency communication system since it will not be easy for TWWC staffs and assistants to use complicated wireless communication system. The manual should include following:

- Location maps of stations for several wireless communication systems
- Diagram of wireless communication system
- List of vehicles equipped with wireless communication system
- Handling of equipment
- Switching methods to generators
- Handling of generators
- Recording and reporting of communication
- Instructions for communication such as concise commands and uniform terminology

7.2.4 Communication System

Collection and analysis of information form inside and outside of TWWC will become very important after earthquake. Communication system inside TWWC and with other organization should be prepared in an effective and correct manner.

(1) Organization for Communication

Internal communication should be done through “Division of Programming and Information”. Quick and correct information should be collected and transferred to “Accident Commanding Office”, which is required to give concise and clear instructions / orders to all the divisions of crisis management organization.

1) Communication with Other Organization

Communication with the organizations outside TWWC should be done in the same manner by Accident Commanding Office. Communication items with TDMO will be as follow:

- Setting up of crisis management Organization in TWWC
- Mobilization and deployment of staffs
- Damage estimation of water supply system
- Information of water suspended area
- Emergency water supply and restoration
- Required assistance from other water companies, military service, police, red crescent and other organizations
- Other important information

2) Avoidance of Misunderstanding

In order to avoid misunderstanding of communication, the following should be paid attention to:

- To decide and make clear the responsible position of communication beforehand
- To unify communication position in order to improve effectiveness and reliability. It is necessary to avoid numeral sources for commanding, inaccurate information and misunderstanding of the information.
- To unify the name used for communication
- To keep records of information and compile

3) Reliable Communication

Required preparation for reliable communication include following:

- To prepare several communication methods since it is predicted that ordinal communication system will be damaged.
- To prepare guideline for communication on type of information and communication manner. The staffs should understand the guideline.
- To prepare format for "information of damage" and other communication
- To discuss details of communication system among the crisis management officers and to improve it.

4) Recording of information

Information should be recorded in a proper manner. The major items to be recorded are as follow:

- Date and time of information receiving
- Name and position of TWWC staff
- Contacted person and organization
- Type of information
- Contents of information
- Response by TWWC staff

(2) Preparation of Several Communication Methods

It will become difficult to secure communication system after earthquake while the importance of communication will increase drastically for urgent activities and emergency restoration. Poor communication methods will disturb the emergency activities. In order to secure reliable communication, monitoring system should be made as earthquake resistant and several communication systems should be prepared.

Quick finding of damage and reliable communication will also contribute to prevention of secondary disaster.

1) Collection Methods of Damage Information

For finding damaged location, following will be useful.

- Telemetry system: For obtaining information of general damage of water supply system, telemetry system is very useful since it is difficult to patrol all the system in a short period.

Damage level of each area will be recognized by observing water flow rate and comparing with the ordinary condition. The information can be used for selection of continuous water supply area and priority activity area. Basic idea for the selection is that water supply will be continued in the minor damaged areas and lots of repair teams will be sent to severe damaged areas.

- Emergency patrol: By patrolling the damaged points or places will be found. Considering the traffic conditions after earthquake, it will be better to use motorbikes for patrolling the area.
- Information from Customers: Education and PR activities to consumers for encouraging the reporting of damage to TWWC will be required.

2) Several Communication systems

TWWC is preparing the several communication methods as listed below

- Telephone and Mobile phone
- Telemetry System
- Fixed type wireless communication system
- Mobile type (mounted on vehicle and potable type) wireless communication system
- Internet

Required number of each facility should be studied, considering the activities of collection and conveyance of information for emergent water supply and restoration.

Other communication system, such as information collection by man (on foot, motorbike) and communication to public by mass media, police and military service should also be used as much as possible. It is also desirable to seek the possibility of satellite communication system. Previous planning of the information system is necessary.

3) Required Reinforcement of the System

Reinforcement is found to be required to batteries for reliable communication in emergency cases. The requirement is summarized below.

- Small sized generator should be equipped with batteries for wireless communication system
- At telemetry system, batteries are quipped for about 24 hours. When longer period of power suspension is considered, mobile type generators should be provided at several offices. When generator is used for lighting and telemetry system only, small size generator of 5 kVA will be required. In order to use mobile type generators, previous set up of switch board is recommended.

(3) Public Relation

Activities of public relation (PR) are important methods for communication with consumers. PR activities will contribute to understanding of the consumers together with increase of information from consumers.

Important items to inform / ask to consumers for earthquake countermeasures are listed below,

- Problems of water supply system. The information on the problems of the leakage and system damage should be give to consumers.

- Securing potable water by consumers. It is required to recommend consumers to store required water for safety even though TWWC retain sufficient water. The storing methods and period for keeping drinkable water quality should also be explained. The recommended volume of stored water by each family will be “3 liter” times “family members” times “3 days”.
- Methods of emergency water supply by TWWC. The consumer should understand the locations of emergency water supply base and supply point by water tanker. The method of water supply by temporary service taps should also be well informed to consumers.
- Cooperation on emergency restoration: Emergency restoration will disturb the life of residents and their understanding and cooperation are required.

It is required to ask consumers to assist TWWC as volunteers for emergency water supply. Training should be given to consumers on how to install temporary service taps and serve water to people. It is also useful to instruct consumers on how to maintain potable water quality by washing water bag in the training of receiving water from emergency water supply base.

Training and education to consumer are better be done in coordinating with TDMO, who is now executing several pilot projects to organize inhabitant group and make them understand the required activities after earthquake. Several seminars and workshops will be held and TDMO is willing to cooperate TWWC for the training.

7.3 Emergency Water Supply Plan

The target of emergency water supply after earthquake is that 3 liters of water should be supplied at every 1 km distance to all the people in water outage area for the initial three days, and then water supply amount should be increased to 20 liters up to 2 week period. As shown in the *Figure 7.3.1*, main water supply bases are the existing reservoirs and existing wells. The number of the base will be increased by setting emergency water supply taps to fire hydrant on restored distribution lines.

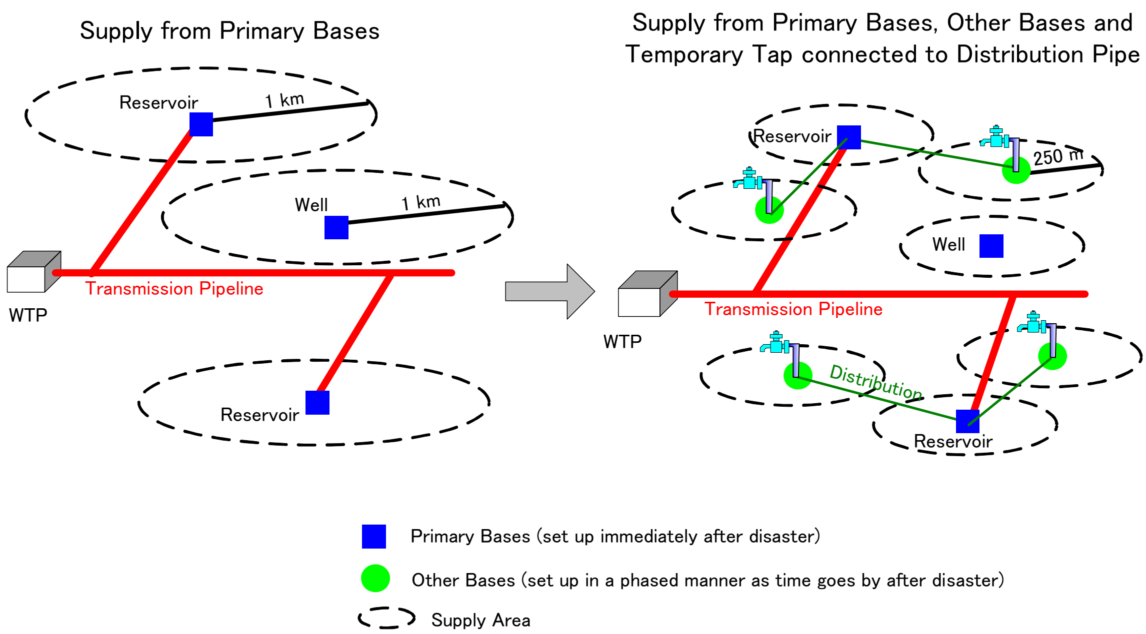

Figure 7.3.1 Image of Emergency Water Supply

7.3.1 Methods of Emergency Water Supply

(1) Preparation of Emergency Water Supply

It is important to prepare emergency water supply for smooth execution of emergency water supply beforehand. The proposed methods for emergency water supply, mobilization of staffs, receiving of assistants form other provinces, and allocation of teams are described herein. For preparation of the plan of emergency water supply, following should be paid attention to:

- Estimation of water supply interrupted population
- Securing methods of drinking water
- Selection of materials and equipment for emergency water supply
- Selection of high priority facilities for emergency water supply. Evacuation places, general hospitals, welfare facilities and other places should be selected for executing emergency activities.
- Initial activities and deployment of required personnel, vehicles etc.

(2) Water Supply at Emergency Water Supply Bases

Consumers in water outage area will get water from emergency water supply bases of every one kilo-meter. The type and location of water supply bases are explained in Chapter 6.4. Existing reservoirs are selected as emergency water bases considering the scattered condition of numerous reservoirs. Special attention should be paid to the security of the reservoir area and avoidance of water contamination.

When water transmission lines are reinforced, water will be transmitted to all the reservoirs just after recovery of power suspension, the period of which is assumed as one week. Until the recovery, stored water in the reservoirs will be used for emergency water supply. Considering the target of emergency water supply, the amount of water to be stored for each person is calculated as:

3 liter x 3 days + 20 liters x 4 days = 89 liters / person

Two third of the volume of water reservoir is assumed to be remained in the reservoir after earthquake, because the capacity of the reservoir is about 24 hours of daily average demand and one third of the this large capacity will be enough for daily demand fluctuation and other daily urgent purposes. A half of the remaining water, which is one third of the volume, will be used for urgent works such as fire fighting, and then the other one third is stored for emergency water supply to people. When reservoirs are not existed in one kilometer distance, exiting wells are selected as emergency water supply bases. These wells have sufficient yield capacity for emergency water supply and generators are planed to be equipped to cope with power suspension. Chlorination facilities are also planed to be equipped to keep safety of drinking water. At the same time, emergency water tanks will be installed to store drinking water in the area of poor groundwater quality.

These emergency water supply bases will feed water to water tankers and emergency cars such as fire fighting. Considering the security matter, reservoirs in water treatment plants will not be used as emergency water supply base for the residents but for feeding water to water tankers and emergency cars.

While TWWC staff should stay in the reservoirs to execute emergency water supply, these works can be done by assistants from other organizations or volunteers in the bases of wells. Basic members for each supply point will be three while additional members for the security will be required in some places.

(3) Water Tanker

Emergency water supply bases should cover almost all area of Tehran since water supply by water tankers will not be easy after earthquake due to heavy traffic and assumed breakdown of many houses. However, water should be supplied by water tanker in the area of insufficient water supply bases. When traffic of road is secured after earthquake, water tanker is very useful to transmit water from emergency water supply bases to temporary tanks to be installed. Water tankers are also helpful in the area of poor water quality or insufficient water supply. It is necessary to appoint residents to take care each temporary tank while TWWC staff should patrol to check the maintenance condition of the tanks. When small sized water tanker is used for narrow road area, water will be directly supplied to consumers from the tanker. It is desirable to supply water at the same place and to avoid confusion by the consumers. When sufficient water cannot be supplied in one time, it is required to do even water supply to the consumers and to inform the schedule of the next supply.

Water should be also brought by water tankers to important facilities, such as general hospitals and evacuation places, when it is required. It is important to secure sufficient number of water tankers after earthquake. It is required to prepare a list of the companies, which is now watering the greens by water tankers, and then to discuss and make arrangement with municipality for emergency usage of private water tankers after earthquake while TWWC is better to keep sufficient number of water tankers for emergency. It is also useful to prepare a list of water tankers owned by other organizations such as military, police, several government offices, and other private companies. Required number of water tankers should be estimated beforehand and reviewed periodically since the number will change after emergency water supply bases are prepared.

(4) Water Supply from Temporary Taps Connected to Pipeline

The number of emergency water supply points will be increased by connecting temporary water taps to fire hydrant when the pipeline is restored and water is filled. It is necessary to select the locations for temporary water taps, which will not to disturb traffic, and to take safety measures, such as setting of barricade. Periodical checking of water quality is also important.

The required member for each water supply point will be three who can be assistants form other organization. The residents in the area and volunteers will be able to perform the key roles for emergency water supply form temporary taps.

(5) Water Supply by Water Bags or Bottles

Emergency distribution of bottled water will be useful to supplement the emergency water supply activities. Procurement or donation of bottled water will be required for distribution. Assistance from bottling companies, which is located outside the damage area, will be helpful and preparation of the list of the candidate companies and previous discussions are necessary.

It is also recommended to consider introduction of water packing machine for water bag or bottling, which was used by several water companies in Japan. When packing capacity of one machine is 2 m^3 per hour and working period is 15 hours in a day, 30,000 of one liter bag can be prepared. When minimum water requirement is considered as 3 liter per person in a day, one machine can prepare water bags for 10,000 people every day. Water bags should be distributed to consumers by vehicles.

7.3.2 Proposed Duty Description for Emergency Water Supply

Sufficient number of emergency water supply teams should be secured just after the earthquake to supply drinking water in the area of water outage. It is very important to strengthen relations with other organizations for assistance in emergency water supply through coordination of TDMO. The candidates of assistant are municipality, water companies of other provinces, Red Crescent, military service and selected consumers. In Tokyo, each district office in the municipality is responsible for emergency water supply to people at water supply bases, while waterworks bureau has responsibility on preparation of emergency water bases and water tankers. This work allocation has big advantage that waterworks bureau can put much efforts on emergency restoration works after earthquake to expedite the recovery. Water supply activities at each water supply base can be assisted by ordinary residents after short training, while water tanker can be arranged by TWWC, private companies, other water companies, and military service.

The number of required water supply bases after North Tehran earthquake is estimated as 112, which are located in water outage area. When 3 persons are necessary at each emergency water supply base, 336 persons will be required in total. Sufficient number of assistants will be required even after progress of repair and decrease of water outage area, because number of emergency supply base in the same area will be increased.

After earthquake, crisis management organization should be set up as soon as possible. Duties of the organization members for emergency water supply are proposed as following.

(1) Accident Commanding Division

The major duties for Commanding Divisions regarding to emergency restoration are proposed as follow:

- To ask assistance from other organizations through TDMO
- To obtain emergency traffic pass to water tankers and other vehicles, which are necessary for emergency water supply, by coordinating with police and TDMO. Emergency traffic pass will be required for vehicles of assistants from other water companies, private companies and others.
- To supervise the Laboratory on water quality management of emergency supply.

(2) Operation Division (Water Supply Unit)

Water Supply Unit of Operation Division should coordinate six water districts to do the following:

- To gather information from District Offices and decide emergency water bases to use.
- To arrange teams for emergency water supply from Financial and Administrative Division and assistants from other organization
- To arrange required number of water tankers and control them.

- To take responsibility of assistant teams from other organizations.
- To arrange material, equipment and vehicle from Supporting Divisions. If number of water tankers is not sufficient, they should request to private companies and /or TDMO for assistance from other cities and other organizations.

(3) District Office

The major duties of each district office for emergency water supply are proposed as below.

- To survey and get the information of damage and report to the Operation Division
- To decide water outage area and inform the Operation Division.

(4) Financial and Administrative Division

Financial and Administrative Division should perform the key roles of emergency water supply in order for technical divisions to put more efforts on emergency restoration. The major tasks are shown below.

- To allocate manpower of emergency water supply from several sections and other organizations
- To execute / take responsibility on emergency water supply to consumer at each bases
- To supply water to water tankers/ fire fighting cars at emergency water supply bases.
- To coordinate assistants including volunteers at site
- To inform Water Supply Section in Operation Division the shortage of assistants and reserved water if any.

(5) Public Relation

The division of public relation (PR) is necessary to prepare the contents of concise PR for understanding and cooperation by the residents before earthquake disaster, and then execute careful and kind PR activities after damage. Previous PR activities by using pamphlet or newspaper will greatly contribute the improvement of PR effects after earthquake. Contents of previous PR activities for making residents understand should include following:

- Location of emergency water supply base,
- Method of water supply,
- Safety keeping measures of water quality
- The methods to get information after earthquake
- Requirements for water storage by residents
- Requirements for preparation of container by residents

Confusion and anxiety of the residents will be reduced if they have sufficient information after earthquake. The major information to be understood by the residents is as follow:

- Water outage area and water supply area
- Damage level of water supply system
- Location and time of emergency water supply
- Progress of emergency restoration
- Measures to keep water quality
- Requirement for boiling water before drinking

- Location of complain and demands receiving by TWWC

PR division should put efforts to announce the situation especially in evacuation places and general hospitals just after earthquake disaster. These activities will reduce number of complains and inquiries to TWWC. PR division should also ask consumers to give information on leakage and others.

(6) Laboratories

Laboratories should have responsibility on checking of water quality during emergency water supply. The possibility of water contamination from outside is increased due to damage of pipes and other water supply facilities after earthquake disaster. This might affect human health and spreading of water bone disease. It is required to reinforce chlorination system and checking system of residual chlorine at sites. Maximum attention should be paid to the safety of water quality at emergency water bases under the responsibility of laboratories. It will be necessary to ask volunteers to check residual chlorine after short training due to increase of frequency and location of checking. Laboratories should take responsibility on the training. Simple chlorination methods for chlorination, such as DPD methods, facilities and guidelines should be prepared and kept at the sites considering that unaccustomed assistants will also handle it. Together with these efforts, consumers should be instructed to boil water before drinking.

Some groundwater contain high nitrate, which might cause cyanosis to infant, especially in southern part of Tehran. If water quality of groundwater is found to be unsuitable for drinking after testing, drinking water should be supplied by water tankers or secured in emergency water tanks and groundwater should be used for other purposes. Emergency water tanks are required to be installed to supplement well water for drinking purpose where water supply by water tanker is not reliable. The same arrangement will be required if the wells locate near factories and there is a possibility of pollution after earthquake. TWWC has now a plan to change water sources from groundwater to surface water by constructing new water treatment plant and installation of transmission main in southern part of Tehran. It is recommended to provide emergency water supply bases connected to the transmission main when the plan is executed.

There is possibility of contamination of groundwater from damaged chemical factories. When it is anticipated water quality should be checked under control of the laboratories. TWWC is necessary to survey and find the possible pollution sources and polluting routes before earthquake. When it is difficult to change water sources, introduction of emergency water treatment equipment using carbon dioxide, hollow fiber or membrane filters, such as reverse osmosis, should be considered. Several waterworks in Japan have these emergency water treatment equipments. The equipment of 1 m^3 per hour capacity can supply to about 300 people in one hour when required drinking water is 3 liter per day for person.

(7) Supporting Division

Supporting Division should take responsibility on storage of materials and equipment. Required materials and equipment should be listed up and prepared as much as possible. It is required to prepare maintenance methods of procured tools and equipment, especially the ones which will not be used until earthquakes occur. It is necessary to distribute the material and equipment at several locations for quick and easy start of the emergency activities. It is recommended to equip at gathering places with required materials such as cameras, cotton work gloves, flashlights, keys for valve, manhole openers, flashlights with generator, fire fighting horse, motor bikes and emergency medical kits. Maps, pipeline drawings, canned food, cooking tools, folding beds and blankets are also required especially for assistants form other provinces.

Warehouse is required to be constructed at emergency water supply base and store following:

- Manual for emergency water supply
- Chlorine (Calcium hypochlorite)
- Simple residual chlorine meter
- Engine pump for water supply
- Temporary pipes and temporary water supply taps

7.3.3 Emergency Water Supply to Important Facilities

Distribution pipe routes to important facilities should be changed with earthquake-proof pipes with high priority. Since the activities of strengthening pipelines will take times and huge cost will be required, several methods should be considered to secure water to important facilities.

(1) Evacuation Place

Emergency water supply bases should be basically set at evacuation places. About one hundred of the evacuation places are selected in JICA comprehensive master plan and get approval by the government. The other places are still under the study and waiting for the approval by the government. Total number of evacuation place will be about 1,000 according to information from TDMO. All of the evacuation places will be open space such as park, playground, and parks.

Considering the required cost and easiness of maintenance, existing distribution reservoirs will be used as emergency water supply base. When the evacuation places are located near the existing reservoirs or other emergency water supply bases, another water supply base will not be installed at evacuation place but supplemental water supply should be arranged by water tankers and emergency water tanks. The ordinary consumers will be required to go to the emergency water supply bases in such areas while the weak consumers will get water from supplemental water supply.

(2) General Hospital

Water distribution system to general hospitals should be reinforced at high priority. By the time of reinforcement, water supply to the hospitals should be done by using available water distribution pipes and water tankers after earthquake disaster. It is also required to consider installation of emergency water tanks at hospitals. Since there is possibility of water shortage even after the efforts of TWWC, it is required to guide general hospitals to secure water by themselves. TWWC should recommend general hospitals to prepare deep wells and generator or large reservoirs. The list of the major general hospitals in Tehran is shown below.

Table 7.3.1 List of Major General Hospitals in Tehran

Name	Required Water (m3/d)	Head (m)	Capacity of W.Tank (m3)	Capacity of Wells (m3/d)	ADDRESS
Ayat Allah Taleghani Hospital					Chamran Highway, Tabnak St.
Akhtar Hospital	90	85	-	-	Elahieh, Pole Roumi, Shariati St.
Amir Almomenin Hospital					Shahrara, Niayesh St.
Shahid Modarres Hospital					Sadatabad,above kag Sq.
Shahid Rajayee Hospital	500	112	-	-	
Shahid Hasheminejad					Vali Nejad St. After Vanak Sq. Valiasr St.
Hedayat Hospital					Hedayat St. Shahrzad Blvd.
Mofid Children Hospital	50	30	-	-	After Hoseynieh Ershad, Shariati St.
Shahid Labafi Nejad Hospital	25	80	15	41 lit/sec	Jafari St. Pasdaran St.
Emam Khomeini Hospital	1000	140		-	Keshavarz Blvd.
Boo Ali Sina Hospital					Imam Hosein Sq., Tehran No Road
Jaber Hayan clinic					Nouri St. No.55, Golnabi St. Pasdaran
Hazrat Fateme					Jamaloddin Asadabadi St., No. 21 St.
Shohadaye Tajrish					Tajrish Sq.
Tohid					Navabe Asadi St. Tohid St.
Shahid Motahari					Shahid Yasami St. Vali Asr St.
Amir Kabir					Koye Daneshgah, North Karegar
Jamaran					Jamaran Sq. Jamaran St. Shahid Bahonar St.
Day					Valiasr St., Tavanir St.

(3) Fire Fighting

About one-third of water in the reservoirs can be used through distribution pipes for fire fighting and other emergency activities while the remaining one-third capacity should be kept for consumers after arrangement of reservoir outlet pipes. Fire fighting car can get water from emergency water supply bases when water is not available from fire hydrant due to damager of distribution pipelines. With the efforts of TWWC, water disaster might not be sufficient for fire fighting after earthquake. Since arrangement with Fire Fighting Organization will be coordinated by TDMO, it will be useful to discuss with TDMO and Fire Fighting Organization on other securing methods of water for fire fighting such as usage of qanat water and groundwater from wells in parks or for irrigation. TWWC should also suggest the organization for preparation of generators to use well pumps during power suspension.

7.4 Emergency Restoration Plan

The target of emergency restoration period is set as approximately four weeks in Chapter 5. Number of assistant teams will largely contribute to the achievement of the target, which is necessary to revise after a certain progress of the activities. In order to expedite the progress, it is better to set short term target, which might be as follow:

- Within 72 hours after earthquake: To start restoration of water supply system
- Within one week after earthquake: To start water supply through restored system.

Preparation for emergency restoration is indispensable for quick recovery of water supply system and minimizing negative effects on the consumers.

7.4.1 Procedure and Methods of Emergency Restoration

(1) Initial Estimation of Damage

Information of damage should be collected just after earthquake even if it is before setting up of crisis management organization. The information will be used for initial judgment of general damage, and preparation of countermeasures of emergency restoration and emergency water supply.

Damage level should be assumed from indication of abnormality in meters and other instrument. Large discharge of water from reservoirs or quick drop of water level in reservoirs will be the signal for the damage in water supply system downstream. Adequate usage of the telemetry system will be very important after earthquake. If damage level cannot be assumed in office due to power suspension and other reasons, site survey of important facilities should be done immediately. Information collected by staff on the way to office should also be used as initial data. For emergency restoration plan, it is required to collect information of damage on other infrastructures such as gas, electricity, communication, sewerage and road.

(2) Patrol of Important Facilities

After initial judgment general damage, patrol should be done to know overall damage by checking intake facilities, damage on bank of dam, appearance of raw water quality, water treatment facility, reservoirs, pumping station and pipelines. It is also necessary to check informed but unconfirmed damage, effects of other damage to water supply facilities, such as road and river, and the suspected location of second disaster by conducting patrol.

(3) Patrol for Finding Damage on Distribution Pipes (By each Water District)

Checking of pipe condition should be started from transmission mains and distribution mains, which are important pipes, and then goes to sub-mains. Locations of high probability of damage along distribution mains should be listed up beforehand and be patrolled with high priority. The most probable points, or weak points, are locations of pipe connection with mass concrete such as reservoirs, valve chambers and major thrust blocks. Location of fault crossing should also be carefully checked during patrol of distribution mains. Figures in Chapter 3 show the locations of distribution pipes which cross faults.

(4) Preparation of Emergency Restoration Plan and Execution

Emergency restoration plan should be prepared as soon as possible after finding damage level and crisis management office is set up properly in TWWC. Decision of priority works, in consideration of importance and urgency, is required for quick start of restoration. Water outage area should be diminished as much as possible by adequate adjustment of water distribution following the process of emergency restoration plan. It is required to consider the items below for preparation of emergency restoration plan.

- To know the condition of the major facilities
- To select safe transmission and distribution mains together with reliable supply area
- To assume damaged / to be damaged transmission and distribution mains and damage points
- To decide restoration period
- To select high priority for emergency restoration
- To select methods of emergency restoration (repair or installation of temporary pipe)
- To secure and distribute required materials and equipment
- To study process of emergency restoration
- To arrange repair teams (members, vehicles and supporting companies)
- To know the restoration of other lifeline such as sewer system
- To keep safety of water quality by strengthening chlorination for resuming wares supply after emergency restoration.

The typical repair works will be a repeat of filling water into pipe, checking water pressure, leak detection or survey, and pipe repair. Restoration of pipes along important roads should not disturb emergency traffic and it is necessary to study previously the methods, which will be either usage of bypass or installation of temporary pipes.

The emergency restoration plan should be revised after progress of the activities considering damage level, assistant’s activities, condition of bypass pipes, water supply interrupted population, sufficiency of emergency water supply, and the priority.

(5) Detailed Investigation

The detailed survey of each facility should be done with staffs, who know well about each facility, to supplement the initial information of each facility. The survey will be done, in parallel with emergency restoration work, to clarify ground condition, detailed damage, and progress of restoration. In order to avoid confusion, all the information should be collected dominantly by Division of Programming and Information Processing and reported to Accident Commanding Office. Damage level of other infrastructures will be collected mainly from TDMO. Finally the research should be done to collect information for future study on the causes of disaster and disaster prevention methods.

(6) Filing of Damage Data and Recording for Permanent Restoration

Division of Programming and Information Processing should investigate damage and compile the records consistently. It is required to prepare format of damage information as described in Section 7.2.3 Preparation of Manual. The survey results should be compiled for each facility and used for deciding restoration methods, procurement of material and equipment, required people for restoration, and allocation of assistants. Location of pipeline damage should be clearly marked in pipeline drawings.

Drawings of emergency restoration of pipe should be recorded properly in order to be used for permanent restoration after emergency restoration. The drawing should explain information of damaged parts, which includes pipe diameter, material, fitting and earth cover. Permanent restoration should be done by replacement of temporary repair or further leakage investigation and repairs, taking into account of future plan. It is important to prepare a format for recording the restoration plan, instruction of repair and daily records of restoration as shown in *Table 7.2.6* and *Table 7.2.7*. Photos of restoration should be attached to the records and filed after restoration.

7.4.2 Proposed Duty Description for Emergency Restoration

Duty description is required to be prepared and distributed to all the related divisions and sections in order to make clear understanding. Proposed duty description of each division is listed below:

(1) Commanding Division

The major duties for Commanding Divisions regarding to emergency restoration are proposed as follow:

- To ask assistance from other water companies and private companies
- To obtain emergency traffic pass for vehicles of emergency restoration, which come from other water companies, by coordinating with police and TDMO.

(2) Operation Division (Water Supply Unit)

Water Supply Unit of Operation Division should coordinate six water districts. Proposed major duties of Operation Division are the following:

- To decide allocation of repair teams to sites considering information from all the District Offices
- To arrange repair teams among districts. Teams should be sent to seriously damaged districts from the other districts.
- To take responsibility of assistant teams from other provinces and decide the water district to work
- To give updated pipe drawing to assistants from other district and other cities
- To coordinate assistance of private companies
- To collect information from each District Office and select priority areas and facilities to be repaired
- To request required material, equipment and vehicles to Supporting Divisions.

- To secure place for waste material and removed soil
- To compile the reports from all the repair teams

(3) District Office

Major duties of each district office for emergency restoration are proposed as below.

- To survey and get the information of damage
- To report damage to Operation Division
- To select and send assistant teams to other district or receive assistant teams upon instructions of Operation Division
- To decide the priority job and allocate repair teams and equipment to the emergency posts.
- To provide required material and equipment upon the request by Emergency posts.
- To secure shortage of manpower and vehicles from private companies. If it is insufficient, request to Operation Division
- To prepare emergency restoration plan of each district.
- To prepare/ update pipeline drawing, which shows location of valves, and give to head office of TWWC
- To give updated pipe drawing to assistants from other districts and other cities
- To list up and summarize the required tools and equipment. Send the lists to the head office. Head office should provide them to district offices
- To arrange location for temporary soil disposal

(4) Emergency Posts

Emergency posts are responsible for actual emergency restoration at sites. The major duties will be below.

- To get information of damage and report to District Office
- To repair pipes starting from high priority area
- To collect reports from all the repair teams
- To report progress of restoration to District Office
- To secure required material and equipment. If they are insufficient, emergency posts should report it to District Office, which will request to Operation Division if they are not available.
- To give guides to assistants from other water districts or other cities

(5) Supporting Division

Supporting Division is responsible for storage and supply of pipe material, heavy machinery, tools and equipment.

1) Storage of Materials and Equipment

Adequate tools and equipment should be prepared for restoration teams and especially for assistants since they might use different type. Pipe materials of large size will not be economical to store if they are not necessary in ordinal times. When the stock of pipe materials and other tools are insufficient, they should be brought from supplier / manufacturer as soon as possible. It is required to ask support and to keep good relation with relevant private companies during ordinary times. Support from private companies will also be expected for other requirements, such as chemicals for water treatment and fuel for generators.

It is recommended to consider following for preparation of storage:

- Pipe material and sleeve coupling for several size of pipe, which will be required for daily leak repair works, should be stored.
- List of material stocked by TWWC should be prepared. After private companies start pipe installation work, list of stocked materials by these companies should also be prepared.
- If emergency materials are insufficient, they should be procured from manufacturers or other water companies.
- It is desirable to prepare list of stocked materials by water companies in other provinces and to exchange it.
- Sufficient stock should be kept for the period until manufactures or other cities can supply them.
- Materials, which are required long period for procurement, are better to be procured beforehand.
- Materials and equipment should be kept in several locations such as emergency posts and other distribution reservoirs in order to take quick actions after earthquake.

Table below summarizes the recommended list of material and equipment for restoration of building.

Table 7.4.1 Recommended List of Material and Equipment for Restoration of Building

Item	Specification	Unit	Number	Item	Specification	unit	Number
wide-flange (H) shapes steel	H-100*100,L=4m	pcs	20	truck with crane		unit	5
I-section steel	I-200*100,L=4m	pcs	20	truck (4t)		unit	5
equal leg angle	L-50*50*6、L=5m	pcs	20	truck (2t)		unit	5
steel tube for tublar scaffolding	3000*ϕ 48*2.4t	pcs	100	Portable Generator	Gasoline	unit	10
clamp for tublar scaffolding	For straghit pipe	pcs	200	Generator	Gasoline, 3.0kVA	unit	5
base plate for tublar scaffolding	For straghit pipe	pcs	50	Welding Machine	Engine type	unit	5
jack for tublar scaffolding	For straghit pipe	pcs	50	Electric Drill		unit	5
log for scaffolding	ϕ 75*4m	pcs	50	Portable drain pump		unit	5
board for scaffolding	36t*200w*4m	sheet	50	Electric Glinder		unit	10
scantling, wooden block	90*90*3000L	pcs	50	Baby Winch	150kg	unit	10
fiber line rope		m	200	Chain block	1 ton	unit	5
wirw rope	ϕ 20	m	100	Jack	Lift 15t, Manual	unit	5
steel wire	#8 ϕ 4.0	m	100				
hole-in-anchor	ϕ 12	pcs	100	General Tools		Set	10
plywood	12*900*1800	sheet	100				
a fire hose	ϕ 50	m	100				
projecter	300W	pcs	20				
welding tool		unit	5				
welding rod		pcs	100				
plastic sheet for construction	1800*3600*0.4	sheet	20				

Notes: 5 sets are considered to be equipped at WTP1,2,3,5 and a Vehicle Base in southern area.

2) Heavy Vehicle

In addition to manpower, it is very important to secure sufficient number of heavy vehicles with their operators for expediting restoration works. Methods for securing heavy vehicles are summarized below.

- To procure by TWWC itself
- To coordinate with other water district offices in TWWC
- To make agreement with private companies. It is required to prepare a list of private companies who has heavy vehicles.
- To request to military force, municipalities and other organizations through TDMO
- To ask assistance from other water companies

The availability in other organizations and private companies should be listed up beforehand.

7.4.3 Other Important Issues for Emergency Restoration

(1) Priority Selection of Restoration

It is required to restore damaged pipes from upstream of the route or main pipes to down stream as described in Section 7.1. Upstream of heavy damaged system has high priority for restoration.

High priority routes to important facilities such as general hospitals, evacuation places, welfare facilities, political facilities and religious facilities should be selected and shown in map. After restoration of transmission mains, these roués should be restored quickly.

(2) Increase of Emergency Restoration Teams

Following can be considered in order to increase number of restoration teams without delay.

- Quick gathering of TWWC technical staff should be secured after earthquake
- Asking assistant restoration teams from other water companies
- Request private companies for assistance.
- Asking retired skilled workers. Previous preparation of list and coordination will be required.

(3) Training

It should be repeated that only a few private companies are working for pipe replacement / installation and have capability of emergency restoration at the moment. It is required for TWWC to give training to private companies. It is recommended to give certificate after they get required skills and then work together during ordinary times in order to retain and improvement the capability of pipe restoration. The contribution of private companies is indispensable for increasing the number of emergency restoration teams and for satisfaction of the target.

Assistant groups of other water companies should have adequate skills for restoration of pipes in Tehran. It is necessary for TWWC to consider the training to them if they are not accustomed to pipe materials in Tehran or their skills are insufficient.

(4) Improvement of Pipe Network System

Improvement of pipe network system, especially "separation of distribution system from transmission system" and "distribution block system", will contribute emergency restoration in following aspects:

- It will become easy to cutoff small pipes, which are easy to be damaged, from important large sized main pipes when the function of transmission pipes, distribution main and sub-main is clearly separated. It will contribute to improvement of main pipes against earthquake and to securing water for restoration.
- It will become easy to increase number of emergency water supply points by keeping function of main pipes
- It will become easy to decide priority of restoration works as it becomes easy to understand water flow.
- By securing function of main pipes, the number of restoration places will be increased.
- It will easy to give the whole water supply block to assistants form other water companies for repair.
- By checking night flow data in each water supply block, it becomes easy to check the leakage after emergency restoration work,
- By isolating each water supply block, water supply interrupted area can be minimized.
- It becomes easy to know damage level and to restore because the area is separated into water supply blocks.
- Backup from the fringe water supply block will become easy

(5) Importance of valve installation

Operation of valves at proper locations is very important for expediting emergency restoration and for prevention of secondary disaster. It is necessary to make clear the location of all the valves for the staff of other sections so that they can also approach. It is also required to check accessibility and condition of installed valves periodically. Whenever necessary, it is required to install new valves without delay.

(6) Securing Water for Restoration

Large amount of water will be required for emergency restoration after earthquake disaster because damaged points are basically found by leakage. In other word, without filling water to pipes, it will be difficult to find leakage. When sufficient water is secured for restoration, water supply can be continued for expediting emergency restoration works even if there are some leakages. It was found that the area with larger amount of water supply could be restored fast after Kobe earthquake. Maximum usage of groundwater should be considered for quick restoration work in Tehran.

The possibility of large amount of leaks is high in Tehran since water is basically supplied by gravity. Therefore it is required to install emergency shut off valves or to arrange pipes at outlet of reservoir to secure water not only for emergency water supply but also for expediting emergency restoration.