Performance and Safety Assessment of Seven Storage Dams in Khuzestan Province, Iran

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Abstract

This study attempted to monitor the performance and assess the safety of seven storage dams in Khuzestan province, including Karkheh, Masjed Soleiman, Marun, Jarreh, Shahid Abbaspour, Dez and Karun 3. Moreover, a GIS database was developed for the dams to assess the structural and non-structural damages, while creating access to a wide range of descriptive information, relevant maps, guidelines and reports concerning damages and rehabilitation plans provided based on two different information levels. The levelone GIS database displays the geographical location of each dams along with layers such as rivers, cities and access roads. The level-two GIS database displays the components of each dams separately on their general plan and also provides information regarding each dam component through Identify. According to previous studies, it can be concluded that the methodology adopted in the current study is applicable to other dams to ensure proper performance and safety expected by project designers and operators.

Keywords: Performance and Safety Assessment, Storage dam, GIS Database.

1. INTRODUCTION

Nowadays, one of the major challenges in the dam construction industry is the poor consistency between modern requirements and functional characteristics of many existing dams. In practice, many dams have lost their capability to fulfill the water and energy generation requirements for various reasons. These include managerial and executive factors, which leads to failure of realization of the project objectives in the design and implementation of dams. There are several factors contributing to that trend, including failure to finance essential and timely credits, weaknesses in design and implementation, insufficient well-documented statistical information about the design of dams, utilization of inappropriate equipment, inferior construction materials and the ever-growing population. By identifying the damage factors and providing desirable solutions, it is possible to achieve the previous (or even higher) structural performance and safety at lower costs. Undoubtedly, this is not possible without proper recognition of the type of damage and its causes.

Performance monitoring and safety assessment of dams aims to ensure the acceptability of the safety and performance of dams in accordance with the expectations of designers and owners. The results will form the most important record on which performance reviews will be based [1].

In recent years, the modern technology of Geographical Information System (GIS) has initiated many developments in design, management and operation [2]. Effective planning and decision-making require access to accurate and up-to-date information. In order to adopt a concentrate data management, it is critical to import all available information into a GIS database [3].

The advantages of information integration include:

- Facilitated use of information in computers
- Facilitated integration of information
- Accelerated information updating in the integrated GIS

GIS-based projects are capable of handling a large amount of different information at minimal cost and in the shortest possible time, providing reliable forecasts for experts and users. GIS is capable of producing a variety of maps at different scales and in different image systems with a variety of colors. Also it is an analytical tool for spatial information. The most important advantage of GIS lies in its ability to identify the spatial relationships between various geographical features on the map [3].

GIS is not merely a means of storing and maintaining a map (recording of cartographic documents), but also provides a tool to store information for specific purposes. GIS links spatial data with geographical data of a particular phenomenon on the map, while data are stored in the form of geographic features in the computer.

This study attempted to monitor the performance and assess the safety of seven storage dams in Khuzestan, including Karkheh, Masjed Soleiman, Marun, Jarreh, Shahid Abbaspour, Dez and Karun 3. At the end, a GIS database was developed for the seven Iranian dams to assess the structural and non-structural damages, while creating access to a wide range of descriptive information, relevant maps, guidelines and reports concerning damages and rehabilitation plans provided.

2. METHODOLOGY

This study was carried out on 7 storage dams in Khuzestan (Iran), including Karkheh dam over Karkheh River, Masjed Soleiman (Godar Landar) dam over Karun River, Marun dam over Marun River, Jarreh dam over Yellow River, Shahid Abbaspour (Karun 1) dam, Dez and Karun 3 dams over Karun River (Figure 1).

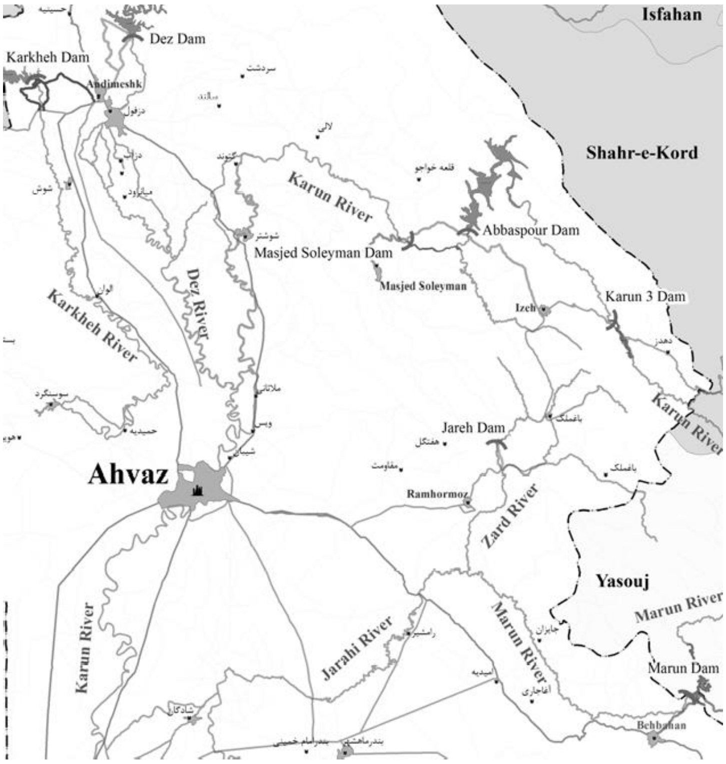

Figure 1- Location of storage dams

The mechanism of dealing with identified damages to the dams and providing rehabilitation plans was determined according to Table (1). Furthermore, the damages were classified into five categories based on type, severity and weakness (Table 2), while prioritizing rehabilitation studies based on severity of damages separately. This study involved the following stages:

1. Identification and investigation of damages found in dams and appurtenant facilities.
2. Identification of cause(s) of damage to predict and prevent factors leading to exacerbation of damage. It also serves to find appropriate and effective solutions to repairing and rehabilitating of the damage.
3. Overall examination of rehabilitation plans for damages or describing services for more in-depth investigation of damages and proposing comprehensive plans for rehabilitation of damages.
4. Providing appropriate solutions and procedures for improving performance and safety of dams.
5. Realizing timely essential measures to prevent or minimize any possible damages to downstream buildings and facilities surrounding the dams.

6. Compiling a GIS database where information about dams and associated facilities are accessible and new data can be added or removed.
7. Examining the quantity and quality of manpower in exploitation of storage dams and providing the employer with necessary advice in those areas.

Table 1- The mechanism of dealing with identified damages to the dams and providing rehabilitation plans [3]

Type I damages	Collecting the previous plans, reviewing and completing plans and estimating the executive operations
Type II damages	Carrying out essential studies and presenting preliminary plans to identify and estimate the project overall costs.
Type III damages	A general assessment of damages and their effects, description of services and estimation of research plans
Type IV damages	Reviewing the current instructions for operation and maintenance, completion and refinement, if necessary

Table 2- Prioritizing damages to dams and providing rehabilitation plans [3]

Priority I	Very severe damages with highly destructive aftereffects
Priority II	Severe damages with moderate destructive aftereffects
Priority III	Moderate damage with weak destructive aftereffects
Priority IV	Low damage with very weak destructive aftereffects
Priority V	Very low damage without destructive aftereffects or with long-term destructive aftereffects

In the first step, the initial information and existing records were collected by holding several meetings with the project employer, executive and stability managers of the dam as well as their proficient experts. The primarily identified damages (structural and non-structural) were listed along with their respective approach to dealing with, significance, future effects and priority. Then, the information and records about damages were requested from the employer, who made available a portion of information. The information included case reports and behavior studies, maps, published guidelines and a few photos related to dam damages and associated structures.

The next step consists of two sections of initial and specialized visits to the dam sites. In the initial visits, after negotiating and discussing issues with the employer, the details of damages to dam components and related facilities were explored. Then, any information inadequacy was resolved by the employer. Meanwhile a part of GIS database was prepared. Afterwards, the expert team did specialized visits to the dam and related structures including the body, abutment, instrumentation, hydromechanical equipment, access roads and dam site. With regard to the primarily identified damages, the expert team members included the specialty of structural, geological, geotechnical and hydraulic. After reviewing the results of visits, additional information was requested from the employer concerning the damage type and severity. The final list and location plan of damages were compiled for each dam.

At the last step, the GIS database of Khuzestan dam was developed to investigate structural and nonstructural damages, while creating access to a wide range of descriptive and spatial information. In addition to providing damage-related reports and rehabilitation plans, the database can easily load information in case an appropriate structure is developed for a web-based system. The key feature in the new GIS database is the dual information levels, each offering different capabilities separately. This database can also be loaded across intraorganizational networks in order to easily gain access to all available information with different levels of access. The new GIS system can update information in all subsequent periods, which provides access to latest information revised at any time interval.

During compilation of this GIS database, it is crucial to design an appropriate structure for implementation. In this regard, two information access levels were developed through data models representing the structure of each level. These data models provided the basis for creating a database at each level.

Furthermore, a suitable structure was developed for storing and encoding additional information concerning each layer. For instance, Figures 2 and 3 display the level-one database structure of Khuzestan dams and level-two database of Karun 3.

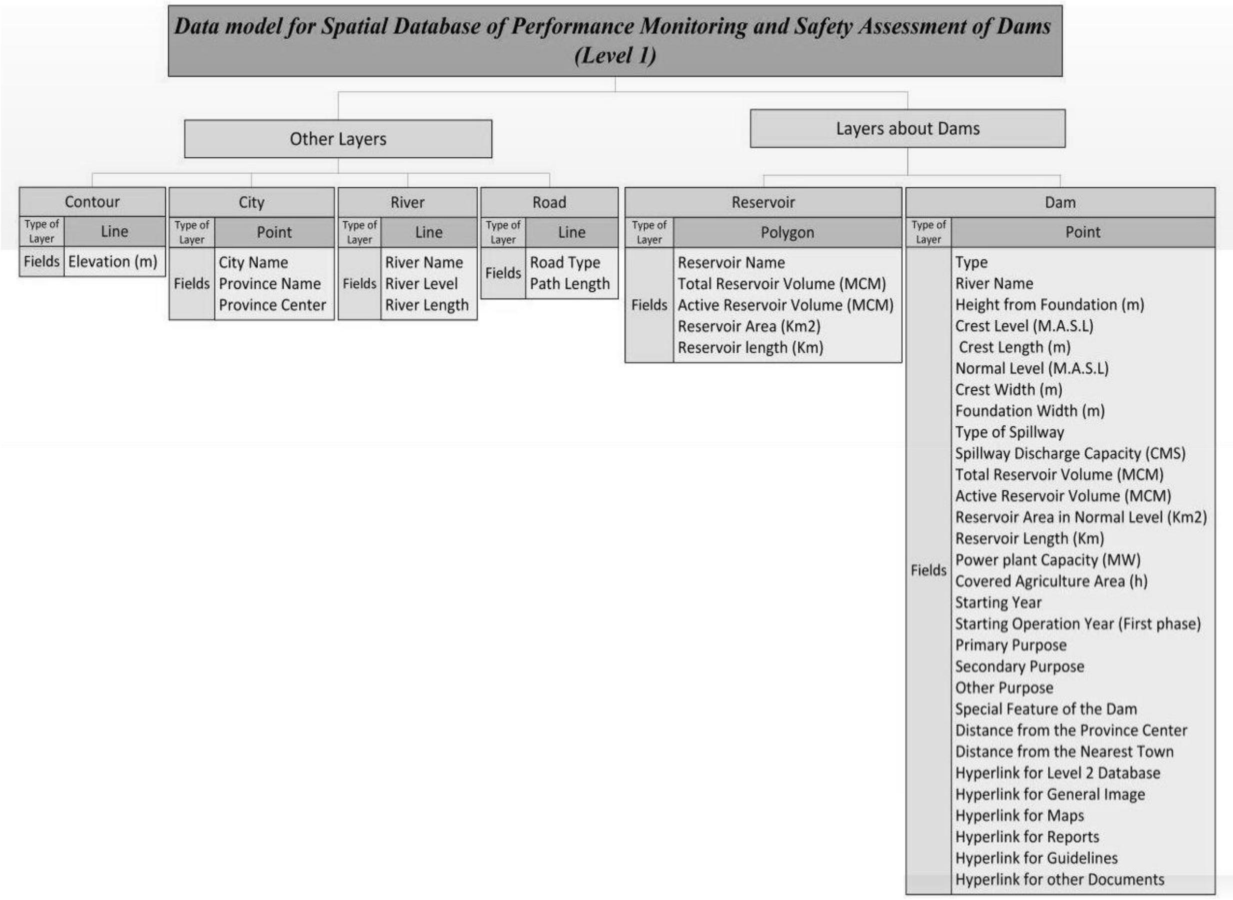

Figure 2- GIS data model (Level 1) [3]

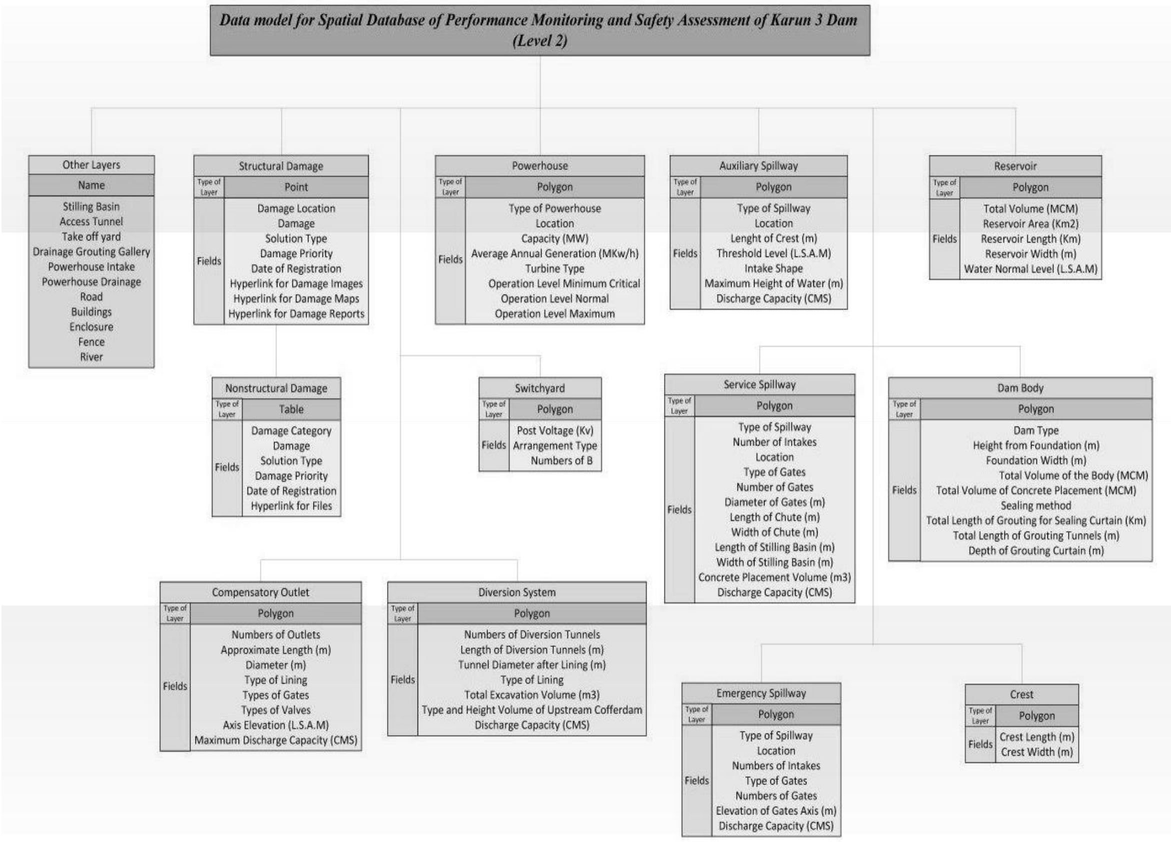

Figure 3- GIS data model (Level 2) - Karun 3 Dam [3]

Prepared on a provincial scale, the level-one GIS database displays the geographical location of each dams along with layers such as rivers, cities and access roads. This level also includes technical and general information about each dam, while all other layers provide descriptive information. In addition to displaying descriptive data of dams, the system provides access to all classified maps, relevant reports, guidelines, and other documents. It is also possible to update all information in every section. In addition, access roads to each dam from Khuzestan central city and nearest cities have been marked down. Figure 4 displays an overview of levelone database along with available access levels to each section.

The level-two GIS database displays the components of each dam separately from a plan perspective. This level also provides information regarding each dam component through Identify. The precise locations of structural damages have been located at this level. In addition to displaying the precise coordinates of each damage through access links, this level provides access to photos of each damage, maps drawn from various related sections, previously prepared damage detection reports and damage detection reports. The remarkable point about the new GIS database lies in accessibility between the two levels. In fact, users can select an option to gain access to level-two database of each dam. The communication process takes place automatically as the user switches between the two information levels. It is necessary to note that all access levels and links have been established according to structures described above. Hence, the database is absolutely dynamic, enabling users to update all information at any stage and add new information. Figure 5 illustrates the level-two database for Masjed Soleiman Dam together with accessible information.

3. RESULTS

The frequency of each damage identified in the dams has been provided by priority (Table 2) as well as the location of each damage in Figures 6a and 6b. As shown in Figure 6a, the frequency of moderate damages with 6 poor destructive aftereffects, low damages with very weak destructive aftereffects and severe damages with moderate destructive aftereffects were more abundant than other types of damages.

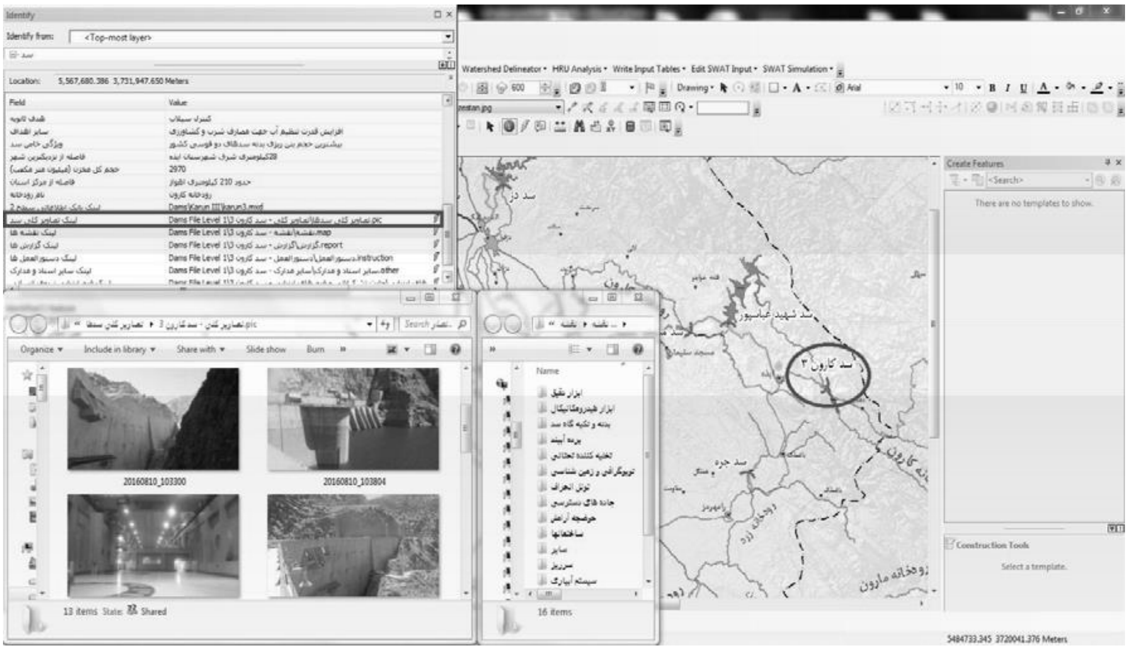

Figure 4- Level-one database and access to information [3]

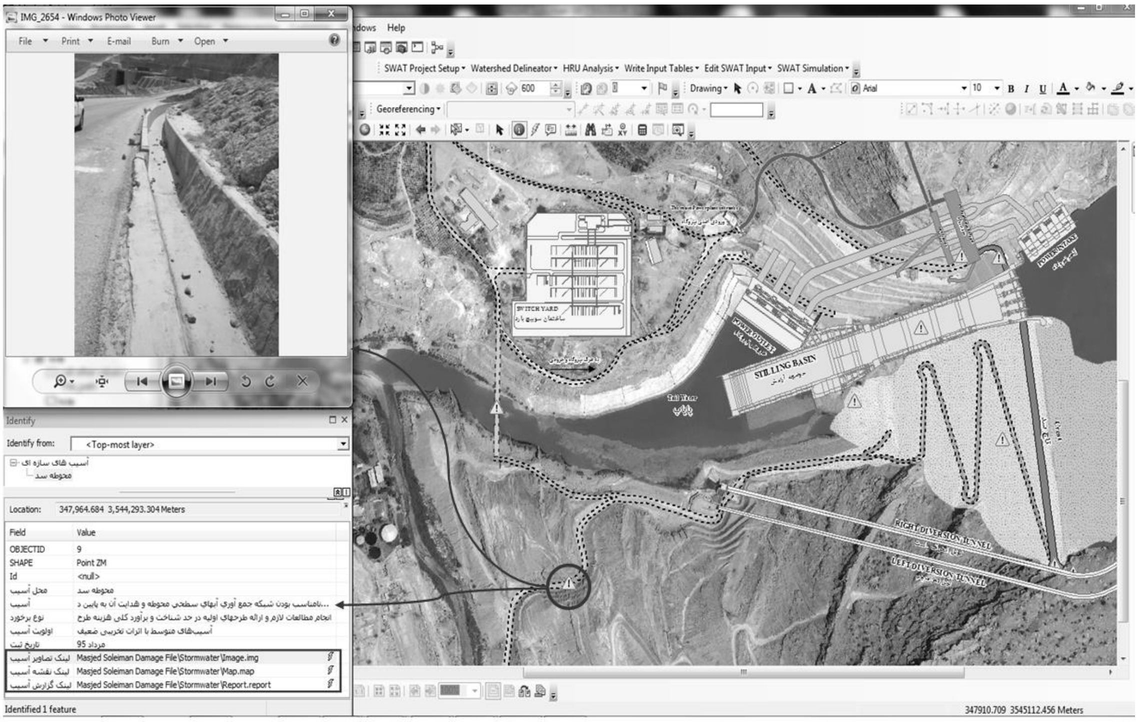

Figure 5- Level-two database - Masjed Soleiman Dam [3]

One example of moderate damages with weak destructive aftereffects is the inappropriate collection and redirection of surface waters at the dams. Considering the important impact of the collection and redirection of surface waters on the performance of other dam facilities and structures, it was essential to initially conduct a field inspection of the dam and identify the current conditions and problems in this respect. Moreover, a comprehensive list of services was provided for drainage studies and collection network of surface waters at storage dams in Khuzestan.

The lack of a proper dock is an example of low damage with very weak destructive aftereffects. Docks refer to coastal structures marking the border land and sea, river or lake at dams. They are also essential components in dam design. Since the function of docks significantly affects their design, it was recommended to employ floating docks as a rehabilitation plan in dam lakes given the prevailing conditions such as high depth, water level fluctuations and location limitations. One advantage of this system is the communication from one dam point to another or even from one dam to another.

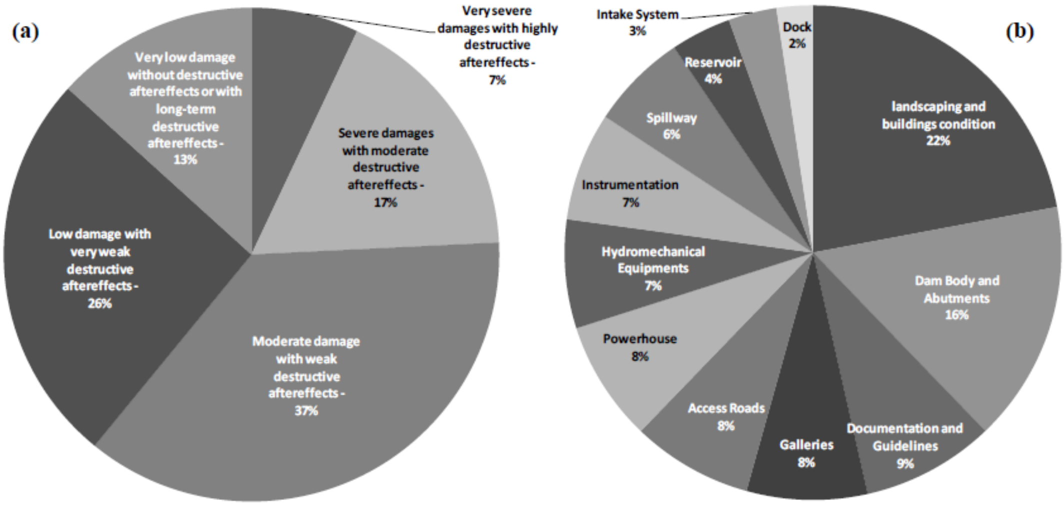

Figure 6- Damages in 7 storage dams in Khuzestan Province by: (a) priority of damages, (b) location of damages.

This type of damage also covers the failure to carry out landscaping and poor condition of buildings in charge of dam operation and maintenance. In this regard, a comprehensive description of services was provided to design dam site plans according to environmental requirements and essential access levels as well as distribution of dam operation and maintenance at different dimensions. This served to develop uniform studies on all dams through integration of spaces required for dam operation and maintenance.

One example of severe damage with moderate destructive aftereffects was instability of excavation rocks and trenches. Collapse in the vicinity of rock mass fractures is the major cause of instability observed in the dam area. Considering the suitable location of the dam with regard to instability potential associated with rock mass discontinuities, the instability near the reservoir does not significantly affect the dam and related structures.

However, it is critical to control debris flows on higher horizons in an effort to prevent damage to related facilities and structures. This partly concerns poorly developed anti-collapse protectors during the dam implementation.

As can be seen in Figure 6b, it can be stated that three major damages observed in dams involved landscaping, body and abutment as well as inadequacy of documents and operating/maintenance instructions.

4. CONCLUSIONS

This study aimed to assess the performance and safety of seven storage dams in Khuzestan (Iran) including Karkheh, Masjed Soleiman, Marun, Jereh, Shahid Abbaspour, Dez and Karun 3 dams. Several specialized field visits were completed and statistical data and behavioral reports were collected to monitor the performance of the dams and assess their safety. Then, the approach to dealing with identified damages to dams was clarified based on type, severity and weakness, while prioritizing rehabilitation studies based on severity of damages separately.

Then, a rehabilitation plan was provided for each identified damage. At the last step, the GIS database of Khuzestan dams was developed to investigate structural and non-structural damages, while creating access to a wide range of descriptive and spatial information. In addition to providing damage-related reports and rehabilitation plans, it is possible to load information easily if a proper structure is created to provide a web-based system.

It can be concluded that the frequency of moderate damages with poor destructive aftereffects, low damages with very weak destructive aftereffects and severe damages with moderate destructive aftereffects were more abundant than other types of damages. Finally, it can be stated that the methodology adopted in the current study is applicable to other dams to ensure proper performance and safety expected by project designers and owners.

5. ACKNOWLEDGMENT

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