A-2 Geological Description of BAZOFT

1. Studies methods and records

The first studies conducted in the basin was the studies of Bazoft-basin with the scale of 1:50000 by Parsab consulting engineers that because of the scale and the wide extend was unfortunately not usable in this studies. The present studies were carried out by using aerial maps with the scale of 1:40000, geological maps with the scale of 1: 100000.prepared by the Oil company. Tpographical maps with the scale of 1: 25000 prepared by the Geographical Organization of the Army and repeated field visits. In this report the stratigraphy, tectonics and faults geomorphology and the land slide potentials of the basin are described.

2. The structural Geology of the Basin

2-1 Tectonics

The studied area is a part of the trustic zone of Zagros. This zone encomprises the highest mountains of Zagros Tectonic movements of the Epirogenic type that have taken place during the whole of geological Era in this zone have not had much effects of the sedimentation presses and stratigraphy of this region, but one of the most important and last tectonic movements have been of the Orogenic type and have taken place in the time interval between Pliocene and Pleistocene. This phase (the period of Alpine folding) cause the folding or the sediments and the stop of sedimentation is sedimentary basins that were the site of thick - layered sedimentation and because of this reason an obvious angular unconformity between the older and newer sediments are observed in the region. The gradual change or the static level of the rivers, the constant excavation action and thin main up-reaches and their deepening are among the effects of gaining height. The Bazoft river and its tributaries are not an exception of this subject.

2-2 Folding

The studied basin is located on a older geological aggregate. In the west of the basin and its elevations there is a lange anticline that in it the anticline axis has been eroded, and from the top of the summit towards the lower parts ,there are Tale - zang, Pabdeh Kashkan and Asmary formations. The layers dip of the under laying formations that have an outcrop in the anticline apex is less, although the surface formations (Aamary) reaches about 80 degrees in some areas. The mass syncline is located in the east of the basin the main formation located on the syncline are Aghajari, Quatemary and rarely Bakhyiari formations. The axis of the folding is similar with the Zagros folding that is North west to South east. The Bazoft liver is flowing on the syncline and the villages of the Basin including Kachooz Bagh - chenar. Dorak. Mazeek. Cham Ghaleh, Tabarok and Ghaleh - tabarok are located on the axis of the syncline.

2-3 Zardkuh Fault (The existing Fault in the basin)

The Zardkuh fault with compress ional reverse pressure is located in the North west–South west direction with a slope towards North east parallel with the south of Ardal Fault at the side and the south - west slopes of Dalanak (h = 3402 m) Kuh-e-charmi (h =4075), Chehel khesht (h = 4018), Kamand (h= 3788) from the Zardkuh mountain range. The Bazoft river flows the direction of Zardkuh fault and parallel to its south - west Part. In the direction of Zardkuh fault Milla, Ilbek and Orclovician formations in Zardkuh pass have been overt rusted on Bakhtyari formation (in the south - west). The Zardkuh fault has been thrusted on Bakhtyari formation (in talc south - west) from the north east-direction and forms part of the border between the High Zagros and Zagros. The length of Zardkuh Fault is at least 130 kilometers there are no exact age or seismic records of the Zardkuh fault. If this fault does have any seismic potentials, by using the existing equitation the magnitude of an earthquake that might take place in the future with a possible 50 % movement in the length of the fault would be about Mb = 7.21. The only seismic data of the Zardkuh fault does back to 1979 with the following specifications.

Data	Time	Eastern longitude	Northern latitude	Magnitude	Depth (km)	S.D	Source
1974.3.12	01:45	50. 155	32.224	4.4	340	0.8	NEIS

3. The Stratigraphy of the Basin

The oldest units in the basin are Sarvak Cretaceous limestone. The lowest margin of this formation indicates sedimentation simultaneous with the advance of the sea. Along with this sea advance Pabedeh marl sediments are observed after the deposit of marl sediments a suitable environment for the sea-creatures specially those having shells is established , as they use the Ca^{2+} ions in the water for building their shells : and after their death. suitable conditions for the sedimentation of the shells and finally the formation of limestone (Tale zany formation) were made ready. Along with the retreat of the sea water because of Eocene mountain forming movements, the Kashkan formations were formed that include the detrital deposits, conglomerate, sand stone and silt stone. This phase of mountain forming that is named Pirrene has caused non-conformity between the Pabedeh sediments and underlying units (Kashkan, Tale zang and Sarvak). After this stage we have the sedimentation of Asmary formation. But the end of Eocene – Oligocene movements caused the vast retreat of the sea along with the erosional non conformity which is observed in the top of Asmary formation. This unit has been covered by the retreating marine Olig-miocene sediments with a fast rate. (Aghagary formation) After this stage we have the Bakhthiari Conglomerate sediments. Because of the mountain-forming phase of Pasadanian (1.8 million years ago) all the Folded units and present face of the basin were formed. In the following the stratigraphic units of the basin are described.

3-1 Sarvak formation

The name of this formation has been derieved front Sarvak pass in Bangestan mountain in the

Khuzestan area. This foliations has two clear faces. The shallow faces that has the remnants of Rodista and Gastropods and the other faces that includes thin layered, small particled dark limestone, that has been Formica in deeper parts and microscopic plague fossils are also found. The shallow faces includes clayey small particle limestone with agro color brown color white-mud limestone with silicate noodles, and brown massive, limestone containing Rodistae. The deep faces includes marl clay dark color marl-clay limestone, thin layered and containing plank tonic microfossil. The age of Sarvak formation is from Albian to Toronian. The top contact of Sarvak foundation with the marl and shale of Goorpay formation is along with erosional non-conformity. The bottom contact of Sarvak formation with the Kajdom formation is confirmative and gradual.

3-2 PE(TZ) : The Grey limestone of Tale Zany Formation

This formation with a gray color and medium to mass layerd is a persistence formation and has abundant fossils. The age of this limestone formation goes back to Paleocene to middle - Eocene. The Tale-zany foundation is an example of pack stone and bioclastic that foraminiferous fossils are found in it in great numbers. In a distant view this formations seems to be a Rific limestone but in fact it is not so. The karstification phenomena in this formation is very obvious. The existence of springs with high water volume and hollows of the ground surface are signs of karstification in this formation, karstification could be divided in two types. A surface type resulting from rainfall and surface waters and a deep type resulting from the effect of ground water. The thing that is obvious and observable in this formation is the existence of numerous springs and signs of the second type of karstification the deep type. Hollows resulting from dissolution cause many problem in the construction of large foundations such as dams and etc, that among them un - suitable load bearing and water-passing capabilities could be liaised. The lower border of this formation is consisted of marls and the sands of Amiran formation and its top border is the Shahbazan formation, this formation is intermingled with Pabdeh formation in the intercalating form in the lateral direction.

3-3 Kashkan Red Conglomerate

This formation consists of red aregenous sediments. Sandstone and conglomerate. The aregenous column of Kashkan becomes large particle towards the top and then forms itsmain panicles and cobbles. The bottom border of this formation is Talezang limestone formation, the top border, considering the lack of stratigraphy in the basin ends to Aghajary formation. No indicator fossil is observed is this formation but fossils such as Milloloidae, Radiolarite and foraminiferous have been found in it. The age of this formation goes back to Paleocene era. The charts making up most of the particles of this formation is resulted from the destruction of Racliolarite rocks. This stratigraphic unit having red color is very well traceable . Some of the engineering characteristics of Kashkan conglomerate. Some of the engineering characteristics of Kashkan formation

Texture coarse	Structure layered	dry weight of volume unit % Yd (g/cm3)	Single Axis Resistance VC(kg/cm2)	Elasticity module Er×104 (kg/cm2)
Rounded	cemented	2.48	1050	35

3-4 Pabdeh formation (Pb)

The name of this formation has been derieved from the name of Pabdeh mountain in Khuzestan. Lithologicaly it includes shale and clayey limestone, accompanied with chert nodules. This formation is along with the shale and marl formation of Gurpi and is confirmative wills it, in the top contact of the Pabdeh formation, the Asmary formation is located that is sometimes confirmative and gradual and sometimes non-confirmative with it. The age of this formation is variable from Paleocene to Miocene. The Pabdeh formation is generally composed of shale and marl and belong to marine environment that was extended to south - east Lorestan, Khuzestan , Fars provinces. Regarding the age range of this formation its Lower contact can be with different formations but in Bazoft basin it is Kashkan, Talezang and Sarvak formations. This formation is intermingled with Talezang formation with a intercalating form.

3-5 Asmary Formation

The name of this formation is derieved form the name of Asmary mountain in Khuzestan Province, and Lithologicaly it includes cream to brown colored limestone and is observable in the outcrops with many cracks and fissures. The Asmary formation in its Lower contact generally covers the shales and marls of Pabdeh formation confirmatively. of course in some parts due to disconformities it is placed on the dolomite and limestone formation of Shahbazan. The Asmary formation includes two parts : The Ahwas sandstone part and the Kalhor anhydrite part.

1) The Ahwas sandstone part. This part is made of the calcareous sandstone and some times of calcareous sand with a little shale.

2) The Kalhor Qnhydrite part: Lithologicaly it includes gypsum. marl and calcareous marl and also thin levered limestone. The gypsum part of this formation is not observed in the studied basin, the marls of this part are green colored and distinguished from the red colored marls of Aghajary. Because of the resistance and special hardness of Asmary limestone, this formations constitute the elevations and resistant parts of folded Zagros and generally form the outer layer of longitudal syncline.

3-6 MP 1(AJ)

These formations are broken to gray colored calcareous limestone with veins of gypsum and deeply eroded siltstones. According to Folks classification are placed in the class of calcitic to chert Arenites from the group of lithic Arenits. Most of the rocks making up the Aghajary formation in the studied basin are made of red marls This foundation is placed unconformativly on its underneath formations. Numerous landslides have take place on this formation, that are described in the landslide section.

4. The study of lithology, topography and geomorphology of Bazoft basin

Most of the deepening of valleys are resulted from weathering and physical and chemical erosion. The weak points of rocks and specially the cracks and fissures resulted from tectonic phenomena are suitable places for more effects of the named factors. In the studied basin most of the old sediments are composed of chemical compounds and in some cases marl sediments that are rock building and are mostly extended in the elevations. Contrarily the detritus are nearly in consistant and mostly relevant to newer formations and make up the low-lying areas.In the studied basin the deposits or Aghajari formation that are riverine sediments are placed on the calcareous marine sediment of Asmary formation. These latter sediments have come out of water in relation to the Alpine mountain making process and formed the old surfaces of the region. Along with the emergence of these deposits that their surface was made of Asmary formation. The Aghajary formation is formed on the top of Asmary formation in a non – confirmative manner and following that Quaternary sediments are formed. This sediments have covered the elevations and low – lying areas of the basin and have formed the present features of the basin. The Bazoft river in the length of its course has eroded the surface sediments and dug into them and flowed on older up reached of Karoon river. Among the factors having effective role on the present features of the basin are neo-tectonical activities that are the result of Zagros zone uplift and related activities. Along with the vertical movements of the Zagros zone (0.5 cm in a year) and according to it. The studied basin we witness the deepening of Bazoft river and its tributaries, more erosion and finally carrying more suspended and dissolved material by flowing water. Climatically changes and also after snow fall are among the other important factors in erosion, flood generation and finally morphological changes in the basin. Lithological factors are also among the other important factors causing morphological changes in the basin. The existence of sensitive to erosion and landslide marl formations in the basin such as Aghajary formation and Quaternary sediments have a great effect in the morphological changes of the basin. It should be noted that the marl horizon in the heights is eroded because of climatic factors and this causes the instability of the calcareous surface pieces and finally the fall of this pieces.

5. The material

The Bazoft river, one of the branches of Karun river, is located in side the studied basin and its original shape has been greatly effected by the morphology and in the next stage the litho logy of' the region. This river in the length of its course cuts through stones with different compositions and litho logy but these deposits are mainly inconsistent and erodable. This river is considered generally of the Braided river type. The sediments of the river bed, margins and meandered sections are mainly large - particled and do not have a special layering and are considered among the youngest sediments of the region. The river bed in the locations of the studied area is widened and a lot of large particled sediments have accumulated in its banks. The small particled sediments of flood plains do not have a lot of extension and thickness. As most of the erosion and transport of the sediments are carried out by flowing water via the water courses it is necessary to explain the water courses network. The erosional water courses could be divided to two classes. One are the water courses effected by mechanical erosion that are named Gullies or. Grooves. This type of water courses could be observed near Ghale tabarok village. The other kind of water courses are made due to dissolution erosion. These type of water courses could be observed in Torked valley. One or these water-courses is Gosalebar river. This water course originates from the North - west of the basin and after passing Torked valley and passing beside Kachooz, Baghcenar. Dorak and Farik villages joins the Bazoft river. Because of the rapid floods of this river in flood season and also the unstable sediments along the Bazoft river which the Farik village is located on , every year in tile flood - season many damages occur in the area, in such a manner that a long wills the flood event the banks oft the flood way are eroded and ultimately there excises the danger of the destruction of Farik village. The erosional water coup are observed in the two branched and parallel types. The branched type is the most frequent type in the region. Parallel water courses have been formed in the rocks or deposits that do not have great resistance to mechanical erosion on their infiltration capability is limited. this type of water course is observed mostly on Aghajary formation in between the Dorak and Baghchenar villages and also below Ghale tabarok village. The severe and constant erosion of small particled sediments by flowing waters has caused. The formation , development and extension and deepening of these water courses. The lack of vegetation cover and high slopes are among the factors that develop these kind of water courses. Another kind of water courses that has been formed on hand and salable rocks, are dissolution water courses. These water courses are wide and deep and have been caused under the effect of dissolutionary erosion in the calcareous rocks of Cretaceous, Permian era and Asinary formation of the studied area. The assistance of cold climate and abundant snow. fall in the heights, snow melt and the carbonate composition has supplied a suitable environment for erosion and the formation of this type of water courses. (Torked pass that Gosalebar water course classes Kuhsefid valley. Labarik valley are examples of these water course).

6. Autochthonous alluvial deposits

Rock and old deposits are decomposed to unconsolidated particle under the effect of mechanical and chemical weathering. During these stages a lot of soluble material are transported and the insoluble material remain on the bed lock. These deposits in the areas having slope are moved under the effect of surface waters as loaded main currents or currents with less viscosity and accumulate at the base of slopes and heights because of the decrease of slope, and form sentiments or alluvial soils. These deposits are generally accompanied with detritus sediments that have been moved mostly due to gravity force. The sediments resulting from chemical and mechanical weathering are spread on bed rock.

7. Large Particles River Deposits (Qal)

Bellow Kachooz village in the lower part of Torked pass along the Gosalebar large particled sediments are observed. Also in the course of Bazoft river beside the studied basin these sediments are seen. These sediments are observed in the bed of the water course, it margin, islets and poi bars. The sediments of the margin of the water course, are in the form of river terraces related to older revering sedimentation. The river beck deposits arc among the youngest sediments of the area. Most of their constituting particles are large particled with the size of rubble – stones. pebbles and are considered as polymictic gravels. The water course bed sediments are unconsolidated and unstable but the margin's sediments have more consolidation and individual particles are not easily separated from each other. The agricultural land, south of Kachooz and also the agricultural land of Ferik village is placed on this sediments. Small Particled Riverine Deposits: During the floods that the speed and water volume or the rivers are increased a lot of suspended material enter the Bazoft river via the water' courses, slopes and main tributaries. After the lowering of water level and decrease of water speed the suspended material settle in the margin of the river, and from small particled riverine deposits. The volume and thickness of this sediments is not considerable in the area..

A-3 Geological Description of SARBAZ

1. *Study Methods And Records*

The only geological studies conducted in the basin, has been preparing the geological map of Behbahan area with the scale of 1:25000 and also the geological studied of Zagros. No studies or physical work has been conducted in the basin concerning watershed management. The present studies have been based on field surveys aerial photos and topographical maps prepare by the survey in Organization of Iran with the scale of 1 : 25000 .

2. Geology of the Sarbaz basin

As the Sarbaz basin is located in the structural zone of the folded Zagros, this zone will be described briefly. This structural unit is located in the South west of Iran and its width is estimated to be 150-200 kilometers, and is probably under thrusted the Zagros mountain ranges. The general layout of this area is nearly Northwest - South east and the sediment are deposit confirmatively. The deposits of this basin have undergone deformation and folding during the Pliocene era. The matter that separates the Zagros folds from the other regions of Iran is its special evolutionary stages that distinct it, that can be categorized into three stages:

a) The initial or platform stage that extended from the Infracamberian era until the mid- Triassic era, and during it sediments similar with the central Iran and Alborz area were deposited, also the salty sediments of the Infracamberian era are similar with the sediments deposited in the east of Suidia Arabia. During this stage some regions were out of water, as Silurian to Permian sediments have not been found in some areas ever during the oil drillings. In the beginning of the Permian era the Zagros area was covered with evaporative sediments and then covered by shallow sea calcareous deposits and shale and lagoon faces until the mid - Triassic era.

b) The geosynclinal's stage in Triassic - Miocene era
In the late Triassic ere this part was separated from the other parts of Iran and changed into a submerged basin (The sedimentary basin of Zagros) and was continually submerging because of the sediments accumulated with a thickness over 10000 meter from the Mesozoic era until the Neogene's period. These sediments were basically made of carbonate materials and marl, sandstone and shale is observed among them more or less. The existence of evaporative sediments and the absence of some short term stratigraphic units are indications of vertical (land making) movements in this sedimentary basin. All these sediments lie on the Paleozoic sediments with conformable stratification during the last phase of Alpine orogenesis (in the Mio -Paleocene)were folded and emerged out of water. After this stage, a lake and river environment were created and the sediments due to the erosion of the high

lands were deposited with disconformity's (and formed Bakhtyari conglomerates) no kind of magmatism or metamorphism is observed as the result of the Alpine orogenesis.

c) The new stage or the stage after Orogenesis

Simultaneously with the sedimentation of Bakhtyari conglomerate during the Miocene - Pliocene the Zagros and in some terms the whole of the Iranian plateau incurred the Pasadenien orogenesis and by this phenomena the Bakhtyari conglomerate and its equivalent the Hezar darreh of Alborz were folded and the present shape of Zagros was formed.

3. Stratigraphy of the basin

The studied basin has 13 stratigraphic units that the oldest is the shale formation of Zagun from the Precambrian era and the newest are the Quaternary sediment of the basin. These formation lie on each other some with conformity and some with disconformities and are the Zagun, Lalun, Milla, Surmeh, Fahlian, Gadvan, Darian, Sarvak, Gurpi, Pabdeh, Kashkan, Jahrum and Quaternary formations. The Kashkan, Gurpi and Sarvak formations, form an anticline in the west of the basin. The famous summit of Dena mountain in the south of the basin is formed of the Sarvak limestone formation. The stratigraphy units of the basin are described in the following:

3-1 The Cambrian Formations in the basin (E)

The three formations of Zagun , Lalun and Milla from the Cambrian era can be observed in the basin and are each separately described:

3-1-1 The shale formation of Zagun

The name of this formation comes from a village with this name in the central Alborz. The thickness of this formation in the "Ragehbavy pass" of Ena mountain is 122 meter according to the measurements. From the view of petrology this formation is totally made of colored shales that range from purple - red to dark blue and the red color is more in the under - neat and increases towards the top. This shales generally have "Mica" and towards the top become gradually sandy, in such a manner that the top part of the formation is constituted of small particle of red sandstones and shale. The overall color of this formation is red and shows more weathering compared to under - lying and top lying formations. The lower and upper borders of this formations seems synchronous with Barut and Lalun formation respectively. No certain kind of fossils have been found in column but according to its stratigraphic situation the age of this formation could be contributed to pre Cambrian

3-1-2 The sandstone formation of Lalun

The petrology of Lalun formation from top to bottom is as:

1- Zagun formation, red colored bladed sandstones, sometimes containing mica, the weathered form of it soft with small particle in sequence with red colored shale, sand stone, silts and siltstone, that toward the bottom of the column become more shale – like. The thickness of the Lalun sandstone in this section is about 383.8 meters. The low border of this formation and Zagun formation is gradual and its top border, Milla formation, is completely obvious. This border is on the top of white colored sandstones that their weathered color is pink and are brittle. The fossil found in this formation is Cruziana that relates its age by considering the stratigraphy of the formation to the lower Cambrian era.

2- Red colored sandstones with thin blade- like layers having small particles accompanied with chevron bedding, sometimes accompanied with green particles (103.6 meters).

3- Red colored sandstones with interbed of green colored sandstones in layers with a thickness of 30 cm to 1.2 meters, sometimes blade - like with cross bedding and glauconitic with small to medium grading (108.6 meters).

4- Red colored sandstones with mid - layers of green colored sandstone some laminar and some with cross bedding, having mass bedding appearance with small to medium grading (304.8 meters)

5- Sandstone with weathered pink color and green colored strips, accompanied with brittle cross bedding with medium to big particles, having non - homogenous lumps of quartz and pieces of alkaline volcanic rocks and other volcanic material, rarely having mica, (259.11 meters)

6- Red to purple shale very silty or sandy accompanied with sandstone layers with a thickness of 0.15 to 0.6 meters (36.6 meters)

7- White colored sandstone with pink weathered color, having medium to big particles, brittle, well graded, laminar to mass (18.3 meters).

3-1-3 Milla Formation

The Milla formation has an outcrop in Dena mountain but its thickness has decreased. This formation has three parts A, B, C. The upper part (C) cannot be observed in the Dena mountain.

Part A (the lower part)

The thickness of this part in Dena mountain is 71.6 meters and from top to bottom is consisted of brown crushed dolomite, gray crushed dolomite, dolomite with medium to large particles. The red shales having silt and dolomite to weathered grey to yellow limestone and red shale are observe intermittently. The age of this layer is contributed to upper Cambrian.

Part B (The top part)

The thickness of this part in Dena mountain is 26 meters. From the view of Petrology it consists of red crushed shale with strips of green shale containing "alt Cost". In this column no fossil has been observed, but by investigating its stratigraphic condition its age could be contributed to mid - upper Cambrian era.

3-2 Khami - Group

This group consists of Surmeh and Hith formations from the Jurassic era and Fahlian and Darian formations from the cretaceous era and are described as following.

3-2-1 Surmeh formation

That has a little outcrop consists of dolomitic limestone with thick to mass bedding, brown to gray clay limestone with little resistance, marl and also limestone and dolomitic limestone with low resistance, marl and also limestone and dolomitic limestone in the top. Lwer border of this formation is Neyriz shales and the top border is Fahlian formation. These layers could be used for distinguishing the border of Jurassic and Cretaceous era layers. The age of the Surmeh formation has been estimated from Paleocene - Jurassic to Neo – Jurassic.

3-2-2 Fahlian formation

This formation consists of brown to gray limestone and is observed, its lower border is, Surmeh formation and its top border is Gadvan formation. Its lower border is accompanied with a dissolution breccias. The age of this formation is considered Neocomian-Aptian era.

3-2-3 Gadvan formation

This formation lithologycalls is consists of dark gray limestone with particles and gray to green marls. Overall this formation is consist of shale, marl and limestone between Darian hard limestone in above and Fahlian in beneath. This formations ago is considered late Neocomian to Aptian era.

3-2-4 Darian formation

The name of this formation has been derived from the Darian village in the south of the type section Formerly this formation was recognized under the name of Orbitolina limestone and Aptian-Albian limestone. Lithologicaly this formation consists of brown to gray limestone with thick to mass bedding, coarse and relief belonging to shallow sea environment that Orbitolina are abundant. The lower border of Darian limestone formation is gradual and compatible with shales marls and thin layer limestone of Gadvan formation. This border is chosen on the top of the highest shale in line with shale and the limestone of Gadvan formation. The contact border of this formation with the highly eroded shales of Kajdom formation is confirmative. The Darian formation is very rich in fossils of which could be named Conical Orbitolina, Discoid Orbitolina, Choffatella deceptions, Dictyoconus Arabicus, pseudochrysalidina conica, and algae such as Hensonella cylindrica, and lithoodium aggregatim. The broken remains of Rodistae could be seen in the whole of the formation. The age of limestone Daryan formation is the Aptian era.

3-3 *Sarvak limestone formation*

The type section of this formation has been measured in Sarvak pass located in the southern limb of the anticline in Bangestan mountain located in the north - west of Behbahan city and north - east of the Pars & Kerenj oil - fields in Khuzestan province. The summit of Dinar mountain is made of this formation. This formation in the type section consists of 821.5 meters of limestone and its petrology

has three parts as following: 254.5 meters base: Dark gray limestone , will nodular bedding, small size particles, clay and signs of small ammonites with thin layers of dark - gray marl as interbed.
- the 524 meters middle part
consisted of coarse , light brown limestone , sometimes with parts of radiate.
- the top 43 meters: Very thick to thick bedding limestone with irregular weathering clad with iron oxides and incurred with brecciate. The lower border of this formation in the type section is gradual and conform with Kazhdumi formation. The top border of the Sarvak limestone formation has sharp distinction with the marls and shales of - Gurpi formation. In this level the Sarvak limestone are eroded and clad with iron containing compounds, that could be an indication of disconformities. the Sarvak limestone formation in the Zagros is usually distinguished with two shallow and deep facieses. The fossils found in the shallow facieses of this formation are: Orbitolina, Dyctyoconella, Ovalvelina, algae and fragments of Echinoids are always seen with these fossils. The fossils had founded in the deep faces includes Planktons such as Rotalipora, Hedbergella, Globigerina, Globotruncana. In this way the age of Sarvak formation is considered from Albian to Turanian era.

3-4 Gurpi formation

The name of this formation is derived from Gurpi mountain in the North of Masjed Soleyman city. The type section of this formation has been measured in the South east plunge of Gurpi mountain, and consists of 320 meters of marl and gray - bluish shales including thin layers of clay containing limestone as secondary layers. The range of this formation is sensitive to erosion and has formed a mild topography. This formation with a partial disconformities lies above the limestone formation of Ilam. This boundary is accompanied with, weathered zone containing Iron compounds. In Sarbaz basin the lower border of this formation ends to Sarvak formation, and consists of layers of purple - colored sandy and silty shales and forms the initial layers of Pabdeh formation. This contact border in Sarbaz basin is along with disconformities. The Gurpi formation in most parts of the Zagros contains fossils of Plankton like Rotalipora such as Globotruncana. The age of this formation contributes with Sontonian to Masstrichtian.

3-5 Pabdeh formation

This formation consists of shale, blue and purple marls and thin layered clay - containing limestone and also thin layered limestone containing nodules of chert. The lower border of this formation ends to shales and marls of Gurpi formation in a un-confirmative manner, the top border ends to Jahrum formation. Anywhere that purple colored shales exists in the base of Pabdeh formation Paleocene fossils are observed in it and the most noticeable of them are Globorotalia, Troncorotaloid, Shister. The age of this formation is considered from Paleocene to Miocene. In the Sarbaz basin in places that this formation has outcrops, (the center and North of the basin) the surface color of the formation is red because of weathering and sedimentation, but the real color of the formation is distinguished along water courses.

3-6 Kashkan formation

This formation consists of red colored alluvial sediments, siltstone, sandstone and conglomerates. The particle size toward the top of the alluvial column of Kashkan formation increases and its pieces and fragments are mainly made of chert. The bottom border of this formation ends to the marl - shale formations of Pabdeh because of the lack of stratigraphy. The top border of this formation ends to Jahrum formation but in Sarbaz basin this bonder is not observed. No Triassic type fossil has been observed in this formation but fossils such as Rotalipora, Radiolare, Miloloides and also Rosalines have been found in it. The age of this formation is from Paleocene to mid - Eocene. This formation could be replaced in a inter fingering manner with Pabdeh formation. The Kashkan formation could be Followed very well in the northern slope of Dena mountain.

3-7 The Dolomitic formation of Jahrum

The type section of the dolomitic formation of Jahrum has been measured in the north of Jahrum mountain in Fars Province, this formation consists of 467.5 meters of dolomitic and dolomitic limestone and the description from bottom to top is as following.

- The lowest part : 35.5 meters mass dolomite with a weathered gray to brown color, the most bottom of this layers has undergone brecciate.
- The mid 162 meter consisting of dolomite with deeper weathering having thin to medium bedding.
- The top 270 meters consisting of mass coarse dolomitic limestone, observable with buff to light brown colour. The lowest border of this formation is Pabdeh's marly formation and its change is gradual. The top border of this formation is with Asmary lime stone formation and is as disconformities.

The most important fossils in this formation are Orbitolina and Alveolina.

The age of the Jahrum formation is from the lower Paleocene to Miocene.

4. *Faults*

The existing fault in catchments , Dena or Dinar fault

The Dena fault is a fault with North , Northeast - South, Southeast direction and with a slope towards the East and North - east and is located in the West Part of Dena mountain with an elevation of 4287 meters. The continuation of this fault passes beside Lokureh (4000 meters), Kateh siah and Tangeh shir mountains in the Isphaha and Kohkiloyeh and Boyerahmad province and Dareh – badamy. Kamaneh, Dallan and Siuook mountain in the Chaharmahal Bakhtyari provinces. The great and sudden difference of elevation between Dena summit and Dena fault which is located at the foot of the mountain is one of the important characteristics of the geomorphology of this expansion of Zagros elevation, that is a result of Dena fault activity. Other important geomorphologic characteristics of this fault is the flowing of Gerdab river along the fault and the creation of the narrow, long valley of

Gerdab - Pagard (in the west of Kamaneh mountain and Darehbadamy mountain) and the Aloony and Javanmardy lagoons (in the west of Sivand mountain) in the depressed valley of Deh – Rashid. Many springs such as Sandegan, Mal-Khalifeh have emerged along the Dena fault in the border of mountain and valley. In Sandegan the Fault wall and the fault depression (the creation of Pagard valley) clearly shows the Dena fault line. This point is also clearly observed in Malkhalifeh. In the western part of Dena mountain in the region of Khoonegan, Dashtedez and Emamzadeh villages along the border between Paleozoic formations (in the Eastern section of Dena fault) and the Bakhtyari formation (in the Western section), the Dena fault is at the foot of a very long alluvial terrace. By studying the geological maps and aerial photos it is observed that the Dena fault in addition to reverse movements also has a important right - lateral movements. This movements cause tension and torsion force on the Northern range of Dena mountain and it seems that Hezardarreh and Chero mountains are shifted continuation of Dena mountain in a right lateral manner. In this case the right - lateral movement along the Pagard valley would be at least 50 kilometers. It should be noted that this right lateral movement has been caused by two faults, the Dena fault and Chero fault, is in En Echlon manner. This right - lateral movement has caused the Semiron river beside the Katteh - Siah mountain with an East to West direction, near the confluence with Gerdab river branch (that flows from Pargad valley towards the south) to be diverted in Khersan village to a North - Northwest direction and after flowing about 8 kilometers towards the North (dextral movement of the river) to flow again towards the west in Rostambeigg village. One of the important geological charchteristics of Dena Fault is the outcrop of the linear salt dome in Bagh behazd Gerdob in the east of Surkh mountain, and west of Sivak, Dalan and Kamaneh mountains. Along this fault in the western part of Dena mountain the Zagun and LaLun formations (from the Camberian era) have been Overthrust on cretaceous rocks, in Tange putak, Tangebaghvey and Tange hara (51°21′23″ - 30°59′8″; 51°25′15″ - 30°55′13″). In the Northern area of Dena mountain in the Western slope of Darehbadamy Mountain and Kamaneh Mountain the Bangestan group rocks (from the cretaceous) have been overthurst on the Bakhtyari formation (from the Peliocene) or the valley. In fact the Dena fault forms a part of the border between High Zagros and folded Zagros and has a length of at least 110 kilometers. As said above the elongation of this formations towards the North and the South in the Eastern part of Dena fault (in the western part of Hezardarreh mountain and Chero) can be an indication of dextral with reverse movement. The correlation of Dena fault with the magnetic lineation of T - 11 is a sign of its deepness and importance. There are no data about the age and seismic activity of Dena fault. If this fault would have seismic potential, by using the existing formula for estimation the magnitude of an earthquake that could be caused as a result of movement in 50 % of the fault would be around Mb = 7.14 with an intensity of × MMI = IX.

A-4 Geological Description of TANG SORKH

1. Previous studies and methodology

The only studies conducted in the Tang - sorkh basin has been preparing the geological map, sheet of Ardekan with the scale of 1; 100000 by the National Oil company. No formal studies on watershed managements soil conservation or flood control has been conducted in the basin. The present studies has been carried out by performing frequent field visits and using arial photos and geological map sheet with the scale of 1: 100000 and the topographical maps with the scale of 1: 25000 prepared by the surveying organization of Iran.

2. The general Geology of the region

As the studied basin is located in the folded Zagros formation zone brief description are included about it in the following: This constructional unit is located in the south of Iran with a width of 150 to 250 kilometers and is probably under thrusted to folded Zagros in some areas. The general layout of this area in nearly Northwest to South east and its sediments are placed on each other confirmatively. The sediments of this basin have been folded in the Pliocene. The point that distinguishes folded Zagros from the other parts of Iran is its special evolutionary stages that could be defined to three stages in short.

a) The initial , or platform stage

This stage has lasted from the Infracamberian to the Triassic and during it sediments similar to central Iran and the Alborz have been deposited. The salty sediments of this stage are similar to the sediments deposited in the east of Suidi Arabia. During this stage some parts have been outside water, as Silurian to Permian sediments have not been found in some areas even in the oil drillings. In the beginning of the Permian the Zagros was covered by continental evaporative sediments that were afterwards covered by the calcareous sediments of shallow seas along with shale and lagoon facieses until the mid – Triassic.

b) The geosynclinals stage of Triassic to Miocene

In the late Miocene this part was separated from the other parts of Iran and become a depressed basin (the sedimentary basin of Zagros or the geosynclinals of Zagros)that was continually under subsidence and the sediments of the Mesozoic to Neogene's accumulated in it with more than 10000 meters thickness these sediments are basically of carbonate material and more or less, Marl, Sandstone and Shale in observed in it. The existence of evaporative sediments and the lack of some short term strata are indications of vertical movements (Land forming) in this sedimentary basin. All of this sediments are placed confirmatively of Paleozoic sediments and only during the last phase of Alpine mountain forming (Mio - Pliocene) they were folded and came out of water. After this stage a lake and river environment was formed and the sediments resulting from the erosion of elevations were sedimented un confirmatively(Bakhtyari conglomerate), no type of magmatism or metamorphism resulted from the Alpine mountain forming phase are observed.

c) The new stage or the stage after mountain forming
Simultaneously with the sedimentation of Bakhtyari conglomerate during the Neo-Pliocene the Zagros and in some terms the whole of the Iranian plateau underwent the Pasadenian mountain - forming and in this way Bakhtyari conglomerate and its equivalent the Hezardareh formation of Alborz were folded and the present features of Zagros were formed.

3. The stratigraphy of the basin

The studied basin has 6 stratigraphy units. The oldest part of it belongs to the Cretaceous and is related to the cretaceous lime stone formation. These formation are Sarvak, Pabdeh, Gurpi , Asmary, Razak and Bakhtyari that are placed confirmatively on each other. In the west of the basin on the Sarvak formation there is a anticline that forms Deli Pookeh mountain. In the following each of the stratigraphy units of the basin are described.

3-1 The Sarvak limestone

The type section of this formation has been measured in Sarvak pass in the southern limb of anticline of Bangestan mountain in the North - west of Behbahan city and north - east of the pars and Kerenj oil - fields in the Kuzestan province. This formation in the type section includes 821.5 meters limestone and its lithology in three parts is as following:
The basal 254.5 meters: Gray limestone with nodule bedding, small particled, clayey and containing traces of small Amonites along with interbed of gray marls.
The middle 524 meters: Coarse mass limestone, with a light brown color, sometimes with parts of Radista. The bottom 109.7 meters of this part contains brown to red colored silicated nodules, in the middle part chevron layering is observed.
The top 43 meters: very thick to thick layered limestone with irregular weathering mixed with iron - oxides and brecciated. The lower border of this formation in the type section is gradually changed with Kajdomi formation. The top border of the Sarvak formation is clear with the marls and shales of Gurpi formation. In this border the Sarvak limestone are eroded and mixed with ferric compounds that could be indicative disconformities. The calcareous formation of Sarvak in Zagros is generally distinguished with two shallow and deep facieses: The fossils that have been found in the shallow facieses are: Orbitolina, Dyctyoconella, Ovalvelina.
Algae and pieces of Echinoides are observed along with this fossils. The fossils that have been found in the deep faces include Planktons such as Rotalipora, Hedbergella, Globigerina, Globotruncana. In

this way the age of the Sarvak formation is considered from Albian to Turonian.

3-2 Gurpi Formation

The name of this formation is derived from Gurpi mountain in the north of Masjed Soleyman city. The type section of Gurpi formation in Pabdeh pass in the south west of plunge in south east of Gurpi mountain in the north of Lali & Masjed Soleyman city has been measured. In the type section the column of this formations includes 320 meters of marl and greyly blue shales and secondary thin layers of clayey limestone. This formation is susceptible to erosion and has formed a mild topography. The Gurpi formation in the type section is placed with a minor erosional un conformity on the calcareous formation of Ilam. This border is also along with a weathered zone containing ferric compounds. In the Tange sorkh basin the lower border ends to Sarvak formation, The top border in the type section is Pabdeh formation. This border is in the bottom of layers of purple colored shale that are sandy and silty and form the primary layers of Pabdeh formation. This contact border in the studied basin is a long with disconformities. The Gurpi formation in most regions of the Zagros includes fossils of Plankton such as Globotruncana. The age of the Gurpi formation in the area is from the Sontonian to the Masstrichtian.

3-3 Pabdeh formation

The type section of Pabdeh formation is located in Pabdeh pass in Gurpi mountain in the north of Lali Oil – field. The column of this formation includes 798.3 meters of clayey sediment that from bottom to top are described as following.

1) The bottom140.2meters includes shale and blue and purple marls and thin layers of clayey limestone as interbed. This part is named informally under the title of "Purple shale"
2) 74.6 meters of gray shales and thin layers of clayey limestone
3) 42.4 meters of thin layered limestone with chert nodules (chert - limestone)
4) 82.4 meters of dark colored limestone. Rarely thin layers of clayey limestone with shale as interbed have been found.
5) The top 458.7 meters consisting of thin layered clayey limestone with shale as inter beds. Some limestone are observed in the highest part of the section that probably belong to shallow environments and contain Bentic foraminifers. The lower border of this formation is the shale and marls of Gurpi formation, and is selected in the bottom of the purple colored shale. The lower border is unconformities. The top border of Pabdeh shale is the limestone of Asmary formation. This border is gradual and confirmative. The age of Pabdeh formation is from Paleocene to Oligocene. The Pabdeh formation is completely a shale - marly unit from the sea environment. This formation is succeeded in some parts with the formation of Amiran, Kashkan, Tale zang and Shahbazan in the interfingering form Tange - sorkh basin.

3-4 Asmary Formation

The type section of the Asmary limestone formation has been measured in the Tangegoltorsh of Asmary mountain. Lithologicaly includes inresistant cream to brown colored limestone that many fissures have been expanded in them and shale layers are also observed a among them. In the type section the lower part of Asmary formation is not observed and probably this part has been changed with the marls and shales of Pabdeh formation. The top border of this formation with the Gachsaran formation and the bottom border with the Pabdeh formation in the type section is confirmative In the Tange - sorkh basin the top border of this formation is Razak formation and the Gachsaran stratigraphic horizon does not exists (Razak has succeeded Gachsaran). This formation has two parts: the Ahwaz sandstone part and the evaporative Kalhor part. The Ahwaz sandstone has been made of calcareous sandstone and some times calcareous sand with a little shale. At the time of sedimentation the sands have been washed and deposited in a calcareous environment and have finally made up the Ahwaz sandstone part. The Kalhor evaporative part is not observed in the Tange - sorkh basin and it seems that only the lower part of the formation, namely the sandstone part is observed and its top border is the Razak formation. In case of the existence of Asmary formation under the Gachsaran formation or similar formations because of abundant cracks and fissures is considered the newest oil - bearing rock, Because of the special hardness and resistance of Asmary limestone this formation makes up the heights and resistant parts of folded Zagros. From the age point of view the Asmary formation starts from the Oligocene and continues to Bordigalian from the lower Miocene.
The Asmary limestone are nearly homogeneous and have sometimes dolomitized Wacke stone and Packestone in them. Elphidium and Miogypsina could be pointed out as the microfossil of this formation.

3-5 Razak formation

This formation includes 774.4 meters of red, green to gray colored, silty marls with little weathering and with some silty limestone. The top border of this formation is Goorymishan limestone and its bottom border is Asmary limestone in a gradual and confirmative manner. The top border does not exist in the Tange sorkh basin. The thickness of Razak formation is variable and (between 150 to 1300 meters) the Razak and Gachsaran formation have been changed to each other by interfingering from the Zagros overtrust toward the south west. The age of the formation in the studied area is from the Itanian to mid – Miocene.
From the point of sedimentary environment, the Razak formation is a marginal faces of Gachsaran and Asmary formations and could be recognized as some - how similar to the upper Red Formation in central Iran.

3-6 Bakhtyari formation

This formation includes conglomerated and chert calcareous sandstone that are placed confirmatively and sometimes unconformativly on older formations in different regions. The type section has been measured in the north of Masjed Soleyman in the deep valley of Landar pass in the place that Karoon river cuts through Bakhtyari formation. In the type section one - third lower part is made alternately of mass resistant conglomerate with relatively little weathering and lenses of conglomerated sandstones and the top two - thirds includes conglomerates that have formed walls. This conglomerate includes well rounded pieces with Big rocks, Rubble stone dimensions that are from the Zagros geological faces eroded in different periods and could be placed in the class of Clast supported. This pieces are cemented together by a calcitic cement that is an indication of fresh water environment. In the Bakhtyari conglomerate abundant particles of chert are found, but the main composition is of limestone particles and pieces and according to Folks classification is considered as a calklitite of litharenite and like sandstones present in this formation could be named chertarenite based on the same classification. The Lower border of Bakhtyari formation with the Aghajari formation is covered in the type section. In fact the exact time and locality relation of these two formations is not exactly clear. At least two kinds of relations exist between these two formations. The first is that Bakhtyari conglomerate is placed with angular unconformity of Aghajari formation and older formations and the second is that Bakhtyari conglomerate is confirmative with Aghajari formation.

3-6-1 The Economic properties of Bakhtyari formation

The Bakhtyari formation is important from the ground-waters point of view, as it has enough porosity. Its porosity is controlled by dysgenic factors such as cementification and natural dissolution of the cements and its particles. This formation is a suitable environment for constructing Fellman type well if it is located in the bank or bed of the permanent rivers, If the percent of chert is high in Bakhtyari conglomerate it could be used for production of "Type 5 Cement".

4. The faults of Tange sorkh basin

In the south west of the Tange sorkh village and also the west of Islamabad village the faults activities has caused distortion and breaking up in the formations of the basin. This fault is a branch of the "Dena Fault" and has all the characteristics of the Dena fault, therefore it is necessary to describe this fault briefly. The Dena fault has a main north, north west-south, south east direction but its secondary branches do not have this direction. The slope of this fault is towards the east or north east. This fault in addition to the pressure movement also has a dextral movement. Along this fault salt - domes have been thrusted out, but this is not observed in the studied basin. The length of this fault is at least 110 kilometers. There are no exact data a bout seismic potentials or age of the Dena fault but in case of the existence of such a potential by applying the customary equitation the magnitude of a possible earthquake with a 50 % imaginary movement along the length of the fault would be around Mb = 7014 and the intensity of the earthquake would be MMI = IX. The activity symptoms of the fault are observable in the form of the breaking up of Sarvak formation and causing numerous stone falls in the west of the basin along the old road.

5. The Geomorphologic Units of the basin

The geomorphologic units of the studied basin can be divided to some general groups on the basis of their different processes and causative factors: The first group are considered as part of the slope movements and the gravity force has had move potential effect in their forming. The second group have been formed under the effect of flowing water. The third group are those that the tectonic and lithologycalls factors have been effective in forming them. In the following each of these units are described briefly.

5-1 The materials and forms resulted from slope movements

The slopes in stability and slope movements under the effect of gravity force happen in susceptible areas. Because of the number of landslides in the studied basin, this subject will be described separately in its relevant section.

5-2 Detrital Matter

The detrital matter of the elevations slopes in the studied basin consist of angular pieces with different composition and dimensions relevant to the original rocks. These particles after being separated from the base rock under the effect of mechanical weathering and other factors have fell down individually or in a mass under the effect of gravity. Factors having role in the formation of the detrital matter are tectonic factors in the first place that are effective in causing fractures and breakings in the rocks. The other effective factor is water freezing inside the fractures cracks and porosities that causes the separation of particles and pieces, and the third factor is the gravity force that plays an important role in the falling down of the separated pieces and their down slope movement. Other factors such as the contraction and expansion under the effect of temperature variation and etc. have had an effective role in the slow downward movement of detrital matter. It the guide map these areas have been marked with an Osign.

5-3 The material and forms resulted from the flowing waters

5-3-1 The water courses network

The transfer and erosion of sediments are mainly carried out by flowing waters via the water courses. Therefore the study of the different forms and the type of their activities seem necessary. Basically the type and extension of water courses network is a function of formation characteristics, lithology, morphology and the climate of every region. Factures and cracks, faults, slope and direction of the layers, the solution rate and composition of the rocks and also the vegetation cover are determinative factors that each have a great role in its own place in the formation and type of the network. Most of the water courses of the basin are erosive and are more dependent of topography, composition or material of the land and are less under the effect of Tectonic factors. As observed in the basin the start of the water courses in the heights has a tree-form This is because of the lithology composition of the heights that is limestone and could not be deepened and takes a tree from and in the lower elevations that its composition becomes marly, because of the geologic condition of marl that is very susceptible the water courses are mainly straight and parallel. In the location of the existing fault in the basin tectonically water courses are observed.

5-3-2 Alluvial and deposits

The rocks and old deposits are decomposed to inconsistent particles because of physical and chemical weathering. During this stages large amounts of soluble materials are transported and thaw in stable material remain on the bed rock, these sediments in sloped areas will start moving under the effect of surface waters in the form of low viscosity flows, and accumulate on the hill-foots and below the elevations along with the decrease of the slope and constitute sediments with alluvial soils. These deposits are mainly accompanied with detrital sediments that the gravity has been their main moving factor. Alluvial sediments accompanied with detritus exsist in many parts of the north and east of the basin on the flat elevations. The sediments resulted of physical and chemical weathering are extended on the bed rock.

5-3-3 The alluvial deposits

The alluvial deposits under the effect of debris containing flows and mud flows have accumulated in the mouth of the rivers and in the margin of the mountains , and are fan shaped and are named alluvial cones. Below the Tange sorkh village (south of the village and adjunct to it) this geomorphologic element is visible. In the guiding map the location of the alluvial cone has been clarified.

5-3-4 The small and big particles of the main flood way

During the floods the velocity and flow in the flood way will be increased and a lot of the suspended material enter the main flood way (The Bashar river) from the water courses and slopes. After the lowering of water level and the decrease of the water velocity the suspended material settle down on the side and bed of the flood way and form alluvial deposits. These deposits are an irregular mix of small and big particles. Landslides and the blocking of the main river are among the factors forming small and big particles during floods. In 1973 a big landslide happened outside the basin near the outlet, this landslide that happened along the Bashar river in the same time with the flood caused the formation of a temporary lake and all the sediments of the flood settled down. After the breaking up of this natural dam, resulted from the landslide, the water drained away slowly and most of the sediments of the flood of the basin remained in the floodway. The geomorphologic features of the basin. In the location of Kolah pary valley there is a very steep cliff composed of hard (Asmary) rocks. The existence of weathering factors has caused such morphological features. The features are formed in cold-arid areas under the effect of physical weathering.

A-5 Geological Description of ZERAS

1. Study Methods And Records

The only studies conducted in the basin, has been the reconnaissance watersheds by the Jame - Iran Consulting Engineers that because the vast extent of the basin and the scale and purpose of the studies, was not so useful in the present studies. The present studies have been carried out by considering the aerial photos with the 1: 40000 scale, topographic maps with the scale of 1: 25000 of the Geographical Organization of the Army and repeated field visits. In this report after initial investigation about the general geology of the area the stratigraphy tectonics, faults, geomorphology and landslides of the basin are discussed and each case is described.

2. Geology of the Zeras basin

As the Zeras basin is located in the structural zone of the folded Zagros, this zone will be described briefly. This structural unit is located in the South west of Iran and its width is estimated to be 150-200 kilometers, and is probably under thrusted the Zagros mountain ranges. The general layout of this area is nearly Northwest - South east and the sediment are deposit confirmatively. The deposits of this basin have undergone deformation and folding during the Pliocene era. The matter that separates the Zagros folds from the other regions of Iran is its special evolutionary stages that distinct it, that can be categorized into three stages:

a) The initial or platform stage that extended from the Infracamberian era until the mid- Triassic era, and during it sediments similar with the central Iran and Alborz area were deposited, also the salty sediments of the Infracamberian era are similar with the sediments deposited in the east of Suidi Arabia. During this stage some regions were out of water, as Silurian to Permian sediments have not been found in some areas ever during the oil drillings. In the beginning of the Permian era the Zagros area was covered with evaporative sediments and then covered by shallow sea calcareous deposits and shale and lagoon facieses until the mid - Triassic era.

b) The geosynclinals stage in Triassic - Miocene era
In the late Triassic ere this part was separated from the other parts of Iran and changed into a submerged basin (The sedimentary basin of Zagros) and was continually submerging because of the sediments accumulated with a thickness over 10000 meter from the Mesozoic era until the Neogene period. These sediments were basically made of carbonate materials and marl, sandstone and shale is observed among them more or less. The existence of evaporative sediments and the absence of some short term stratigraphic units are indications of vertical (land making) movements in this sedimentary basin. All these sediments lie on the Paleozoic sediments with conformable stratification during the

last phase of Alpine orogenesis (in the Mio -Paleocene) were folded and emerged out of water. After this stage, a lake and river environment were created and the sediments due to the erosion of the high lands were deposited *with disconformities (and formed Bakhtyari conglomerates) no kind of* magmatism or metamorphism is observed as the result of the Alpine orogenesis.

c) The new stage or the stage after Orogenesis

Simultaneously with the sedimentation of Bakhtyari conglomerate during the Miocene - Pliocene the Zagros and in some terms the whole of the Iranian plateau incurred the Pasadenien orogenesis and by this phenomena the Bakhtyari conglomerate and its equivaleut the Hezar darreh of Alborz were folded and the present shape of Zagros was formed.

3. Stratigraphy of the basin

The Zeras basin has 5 stratigraphic units the oldest of them are Jahrum and the newest are Quaternary deposits. These formation that are lie confirmatively from old to new are: Jahrum dolomite formation, Gachsaran marl , Shale, Limestone and anhydrite formation, Aghajary marl formation, Bakhtyari conglomerate and Quaternary sediments. All of these formations confirmatively and as a anticline, that its axis lies near the Karoon river, and lies with Northwest South east direction. The existence formation in basin form the southern limb of anticline. These formations are folded due to Alpine orogenesis and obtain their new feature. The Details of each stratigraphic units of basin is as following and their location is presented is appendix map.

3-1 Jahrum dolomitic formation (Ja)

Jahrum formation consists of limestone and dolomitic limestone that from the base to top are as following: The base part is consists of mass dolomite with weathered gray to brown color and brecciated, the mid part consist of dolomite with deep weathering, along with thin to medium bedding, the upper part consists of mass dolomitic limestone, coarse and observable light brown to dark yellow. The Jahrum formation is locate confirmatively above the silty marl and dolomitic formation of Sachun. The lower border of Jahrum formation in some area is seen with Kashkan, Tarbur and Pabdeh formations. The lower border of Jahrum formation is mostly obvious and sharp. But this border in contact with Pabdeh gradual. The upper boundary of this formation is Asmary formation and is located in a situation in stratigraphic column that above it lies limestone with regular bedding and conglomerate with ferric compounds. This lithology indicates disconformities at top of the Jahrum formation. The age of Jahrum formation is from Paleocene to mid Miocene.

3-2 Gachsaran formation

The lithology of Gachsaran formation consists of salt, Anhydrite, Colored marls, Limestone and Bitomina ferrous shale. In some parts of this formation silvite (Kcl) is found . at surface instead the

Anhydrite mostly Gypsum is observed and rarely salt has been founded. According to James and Wind Classification this formation is divided to 7 parts following

Part 1) with 39.6 m thickness is called cap rock. This part is a alternation of thick bedding Anhydrite with thin marl layers and sometimes with oil shale. This part is located above the Asmary formation confirmatively. In oil drilling this part has an important role. Because at its lower contact the high pressure of Gachsaran turned into low pressure of Asmary formation.

Part 2) This parts thickness is about 113.5 m and mostly consists of a thick bed of salt. That some Anhydrite and thin limestone layers are observed. Due to tectonically forces between this part and two upper parts , part 1 and part 2-5, nonhomogenous folding is caused.

Part 3) With thickness about 225 m and consist of two unit: the lower unit is made of Anhydrite and rarely salt, But in the upper unit a alternation of Anhydrite, thin layer limestone and marl is observed.

Part 4) The thickness of this part is 834.5 m and is consist of thick layers of salt that is a main compound of this formation with marl, gray limestone or Anhydrite.

Part 5) Its thickness is 308 m and alternation of Anhydrite and red to gray marls is observed in it.

Part 6) With a thickness about 278 m. But about 103 m of its base is a alternation of Anhydrite with red marl and limestone. The mid part is consist of salt and Anhydrite and upper part (61 m) is made of Anhydrite with red or gray marls.

Part 7) This part is covered confirmatively by Mishan formation and is a alternation of Anhydrite and gray marl and sandy limestone , that its total thickness is about 137 m.

3-3 Aghajari formation

This formation consists of gray-brown calk-sandstone and red marls with veins of Gypsum and red siltstone. Usually the sandstones are light weathered but marls and siltstones have deep weathering. Aghajari sandstone formation according to folk classification lies at calkarenite to chertarenite class from litharenite group. Aghajari formation in Lagrus zone is indicated with two faces . One of them is sandy and other faces is marly (has margin characteristics). The main faces in this basin is red marl faces. The lower border of Aghajari formation sometimes sharply and mostly gradual turned to Mishan formation, and is selected at the top of the first generation of marine gray marls. The upper border of Aghajari formation with and without Lahbari unit ends to Bakhtyari formation. This contact sometimes is gradual and conform and sometimes is sharp and no conform.

3-3-1 Lahbari Detrital Unit

This unit is composed of siltstone, silty marl, calcareous sandstone and gypsum. At the upper part of this unit nodular sandstones are observed. The color of this deposits is light brown to gray. The other characteristic of this column is that it is grain size increases up ward. Because of gray color of Lahbari unit sometimes it is not easy to identify this unit from Recent alluvial that are result of rework of Aghajari and Bakhtyari formation. In some synclines of mountainous front, sometimes layers of conglomerate at base and inter this unit are observed. Lahbari unit makes the upper part of Aghajari formation. The lower border of this unit locates confirmatively above the sandstones and red marls of Aghajari formation, that has cliff form. The specification of Lahbari unit from Aghajari formation in everywhere is not easily possible, because this specification is defined in term of light brown or gray color and Lahbari deep weathering respect to Aghajari formation. The top border of Lahbari unit ends to Bakhtyari formation and sometimes ends to recent alluvial. This border is observed in two case of confirmative and non confirmative. Aghajari formation is resulted from erosion of *Zagros mountains in the Aghajari column toward top of column the grain size increases and at upper* part cobles or conglomerate is observable. Aghajari formation in Zagros zone does not have a unit age and from Northwest to southeast and from Northeast to Southwest being younger. According to Isothickness map of Aghajari and Bakhtyari it can be understood that the thickness of this two formation decreases from Dezful depression toward south and Southwest and Mishans thickness increases. Because of this reason we can consider simultaneous Aghajari and Mishan formations and Because of this the presented age for this formation is varies from mid-Miocene to Pliocene.

3-3-2 Sedimentlogy Properties of Aghajari formation and Lahbari unit

The Aghajari formation is a alternation of cycles that become large particle toward up. Each cycle has a thickness between 10 to 100 m. A common column contain sandstone layers with a thickness between 2-5 m and above it a thick layer of marl that is alternative with thin layers of siltstone and fine sandstone. A common column contains mud Pebble log or inter formation conglomerate with cross bedding in medium size sandstone along with rip mark, laminated or massive red marls with veins of gypsum, mud cracks convolute lamination, gypsum veins with a thickness about 10 to 50 cm between red marls, siltstones and fine grained sandstone, along with sign of vegetation fossils, foot traces and Gastropod fossils. The sandstone of Aghajari formation is composed from sub-well rounded carbonate-silica grains, that 70-75 % of them is carbonate and other 25-30 % is silica that 7-10 % of silica is Quartz and other part is chert or water bearing silica (Motiei , 1980). The Lahbari unit toward up becomes large particle and at the base of each cycle 1-3 m conglomerate is observable, and above it a pebbly coarse sandstone with 1 m thickness and with cross bedding is located and toward up changes to fine sandstone, siltstone and laminar clays with sedimentary structures such as cross bedding and ripple marks. The conglomerate of Lahbari unit towards top of this unit become thicker and finally changes to Bakhtyari formation. The Lahbari conglomerates are mostly detrital and are consist of fine cobbles. The Lahbari sandstones from grading view point are similar to recent sandstones. The sorting of this sandstones is good but toward the top of each cycle being weak. And the roundness of sand stone particles in Power scale is 10 % angular to sub angular and 90 % have sub-rounded to rounded form. The shape of quartz particles of this sandstone is angular quartz, clear quartz and Idiomorphic quartz.

3-3-3 An Interpretation about sedimentary environment of Aghajari formation

The Aghajari sedimentary cycles toward up become small particle, this probably indicates river sediments that has been flowed toward south west. Sandstones are signs of horizontal continuation of Point Bar and clay stones are signs of continuation and to flood plain sediments. Probably the veins and layers of gypsum are resulted from evaporate of seasonal lakes, that are located between alternation of siltstone and fine sandstone layers. Sandstones can be signs of levees deposits or can be sign of existence of crevasse splay. If we compare this sediments with known sections, the upper part of this cycles shows some thicken. Probably the Lahbari unit is a intermediate column of Meander sediments (Aghajari) to Braided River sediments and alluvial fan of Bakhtyari formation. Although the change of grain size from fine to coarse toward top of each cycle is a sign of point bar, but the existence of conglomerate indicates the expansive floods with maximum sedimentary thickness in channels that is a characteristic of braided river, thickness in channels that is a characteristic of braided river, therefore the effective factors in Lahbari unit causes horizontal continuation of braided river and finally flood plain deposits.

3-3-4 The Industrial properties of Aghajari formation

The sandstone of this formation are used as foundation rocks in Building construction. The permeability and resistant of this sandstone is variable in different points. Chemical, physical and radiometric analysis has been conducted on the marls of these formation for production building bricks from them but the results have showed that they are not suitable for this purpose. Deep and semi-deep drillings to obtain groundwaters have had positive results.

3-4 Bakhtyari formation $\left(P_b^c\right)$

This formation includes conglomerated and chert calcareous sandstone that are placed confirmatively and sometimes unconformativly on older formations in different regions. The type section has been measured in the north of Masjed Soleyman in the deep valley of Landar pass in the place that Karoon river cuts through Bakhtyari formation. In the type section one - third lower part is made alternately of mass resistant conglomerate with relatively little weathering and lenses of conglomerated sandstones and the top two - thirds includes conglomerates that have formed walls. This conglomerate includes well rounded pieces with Big rocks, Rubble stone dimensions that are from the Zagros geological faces eroded in different periods and could be placed in the class of Clast supported. This pieces are cemented together by a calcitic cement that is an indication of fresh water environment. In the Bakhtyari conglomerate abundant particles of chert are found, but the main composition is of limestone particles and pieces and according to Folks classification is considered as a calklitite of litharenite and like sandstones present in this formation could be named chertarenite based on the same classification. The Lower border of Bakhtyari formation with the Aghajari formation is covered in the type section. In fact the exact time and locality relation of these two formations is not exactly clear. At least two kinds of relations exist between these two formations. The first is that Bakhtyari conglomerate is placed with angular unconformity of Aghajari formation and older formations and the second is that Bakhtyari conglomerate is confirmative with Aghajari formation.

3-4-1 The Economic properties of Bakhtyari formation

The Bakhtyari formation is important from the ground-waters point of view, as it has enough porosity. Its porosity is controlled by diagenic factors such as cementification and natural dissolution of the cements and its particles . This formation is a suitable environment for constructing Fellman type well if it is located in the bank or bed of the permanent rivers, If the percent of chert is high in Bakhtyari conglomerate it could be used for production of "Type 5 Cement".

3-4-2 Some points about the two Bakhtyari and Aghajari formations

Because of no difference in the mineralogy of the Bakhtyari, Aghajari and the Lahbari sections these sediments after the Gachsaran could be considered as synchronous with the organic. This shows the existence of a Mollase faces.

- The advancing of continental sediments or the increase of the hydraulic gradient of the rivers entering the basin because of the rise of the mountainous front has cause the creation of these two formations. There fore the Aghajari formation is resulted of the lowest part of a meandered belt in a alluvial plain or fan. The Lahbari section has been trans located locally by the large braided rivers on the ground surface and probably formed a alluvial fan in the Interfan of Most distal area. The Bakhtyari formation has probably been deposited by the braided rivers in the higher area of the big and small proximal alluvial fan in the Piedmont near the origin.
- The red color of the deposits of the Aghajari formation has originated from the color of Razak formation.
- The maximum expansion of the Bakhtyari formation exists in the foot of mountainous fronts and bends.
- The Bakhtyari formation is equivalent and younger than the Aghajari formation.
-

4. The Faults

There are no faults is the studied basin but the most important fault near the basin is Gazolik fault. This fault is located in the north- east of the basin and has 20 kilometers distance with it, at the South-west foot of the Govehanc Haft-cheshmeh mountain 3972 meter high in the Chaharmahal va Bakhtyari province. The length of the fault is 70 kilometers and has a north west-south east direction and is continued in a barded form with a slope towards the north-west. Near the Haft-cheshmeh mountain the activity of this fault has pushed the Bangestan group formation on the surface formations. There are no exact age or seismic data of Gozolik fault in land. If the fault has any seismic potential by using the existing equitation the magnitude of an earthquake that could happen in the length of the fault with an imaginary 50 % movement of the length would be about Mb = 6.44.

5 Investigating the susceptibility of the basins formations to erosion and their effects on the geomorphology :

Most of the excavations and the deepening of the valleys has been the result of the susceptibility of Aghajari and Gachsaran formations to erosive factors. Because of the chemical composition and the mineralogy of these two formations that are mainly composed of marl and evaporative deposits the material are dissolved in the area with the start of rainfall and will leave the basin in the form of sediments. Along with the continuation of the hydrologic erosion the present morphology of the basin has been formed. The Karoon river in the length of its course has eroded the very susceptible deposits of its bed and banks and as discussed in the landslide section has caused a number of landslides in the margin of its flood way. The fluctuation of the surface water is the main reason of these movements. One of the factors that has a great effect on the basins morphology is the tectonically activities of the basin that has caused the uplift of a part of the basin and also as the basin is located on an anticline the activity and up lift of the Zagros zone and consequently the anticline of the basin has caused the increase of the slope and finally the deepening of the water courses and increase of erosion. The occurrence of floods in the basin has had an effective role in causing morphological changes are observed in the basin. All of the stated cases are because of the susceptibility of the regions formations to erosion.

6. The material resulted from surface water activity

The Karoon river is located in the south of the basin. The general shape of river is determined by the lithology and morphology of the region. The river erodes susceptible formations along its course and carries them as dissolved and suspended load - One of the susceptible formations are the Aghajari deposits that the river dissolves in its course by passing the southern part of the basin. The reason of the muddy water of the Karoon river is also the existence of marl deposits along the course of the river. In addition to this the existence of tributaries that join the river are the other factors that cause erosion and sediment transport in the basin m there fore it is appropriate if the construction of sediment trapping check dams. On the water courses network is more investigated. The existing water courses in the basin are of the eroded type and the existence of this type of water courses is mostly a function of the topography and the earth material. The eroded water courses are them selves divided into the two classes of mechanical and dissolutionary. Most of the basins water courses are of the mechanical type that are named a gully or groove water courses and could be observed in the middle parts of the basin. One of this water courses is located bellow the Davoodiha village and its existence caused the destruction of Ghalamzan and Dareh - gazoon village 25 years ago. Of course the susceptibility of the formations below the village and flood forming rain falls has caused the destruction of the village. The eroded water courses are observed in the basin in the two branched and lateral shapes , in the region. The lateral kind observed more in areas with a stronger erosion.

Table A-3(1) Summary Table of Geological Features Vastegan

Age	Geological Map Legend	Classification Code	Stratum/Formation (Fm.)	Lithofacies/ Sediment Type	Mode of Occurrence and Distribution	Engineering Geological/Geotechnical Characteristics	Remarks
Quaternary Alluvium	Qal	Ri	River deposits	Rounded pebbly to cobbly gravels (10～50 cm in diameter), sand, silt and clay	Confined to 20～30 m wide fluvial landforms in the vicinity of Vastegan village. *Seems to occur as broad cover although it is not ascertained yet.*		
	Qt_3	Al	Alluvium	Lacustrine sediments comprising mainly clayey material	Distributed in certain parts of this area. But in adjoining areas, forms wide plains where swamps are partially developed.		
	Fd	Fd	Fan deposits	A mixture of rounded pebbly to cobbly gravels (10～70 cm in diameter), sand, silt and clay	Fan-like occurrence within gently dipping slopes adjoining alluvial plains. Although this formation is divisible into three units by age, there is similarity in geological composition. Therefore, for engineering purpose, it can be considered as a singular unit.	Stable. In a part of Vastegan village, river erosion is active.	
	Dt	Dt	Detrital deposits	Subangular pebbly to cobbly gravels (up to 30 cm in diameter) filled with mainly clayey material	Distributed within the mountainslopes. Thickness of the Formation is about 3～8m.	Small-scale ground failures caused by roadside works and river erosion are present in certain parts.	
Quaternary Diluvium	Qt_2	Te-1	Lower terrace deposits	Sand ,Gravel, Silt	Distributed in a very small area forming belt-like planation surface	Weakening of the formation due to snow-melting.	
		Te-2	Middle terrace deposits	Sand ,Gravel, Silt	Distributed in a very small area forming belt-like planation surface	Apparently no problems.	
Eocene Paleocene	E^{d}_{1} KE^{m}_{s}		Tarbur Fm.	JAHARUMS Dolomite with Thick-intermadiate Bedding SACHUNS Green and Red Marl and Sandstone			
Upper Cretaceous	K^{l}_{t}			Tarburas fossiliferous Limestne			
	K^{m}_{g}		Gurpi Fm.	*Gray Marl with minor occurrences of Sandstone*	*Distributed broadly in the SW end of the study area.* Extremely brittle marl is dominant. Exhibits hilly landforms, throughout the area, resulting form surficial erosion. The source region of the tributaries draining the area occupied by this formation is represented by cliffs showing erosional features.	This formation is the source of generation of mud flows occurring snow-melting and heavy downpours. These mudflows cause damage to the farms downstream of Vastegan. The hard rock belt running from NW to SE within the study area plays the role of sediment erosion control dam (sabo dam). In the upper reaches, however, artificial erosion control works are required.	Most problematic geological unit in the investigation area.
Lower Cretaceous	K^{l}_{sv}		Sarvak Fm.	Well-bedded to massive creamy to white Limestone & Marl	Distributed from NW to SE of the study area. As the major constituent is hard rock represented by limestone, and the contribution of marl is small, the mountainsides are stable. Some parts may act as the source for blocks leading to accumulation of scree/talus deposits. But no significant problems are seen.		
	K^{ml}_{k}		Kazdomi Fm.	Gray Marl, thinly bedded dark argillaceous Limestone with Chert	Though hard, the stratum is somewhat brittle with visible evidences of cracks in the surficial rock. Due to narrow and limited occurrence, *this formation is not that problematic.*		
	K^{l}_{d}		Darian Fm.	Thick-bedded to massive dark gray Limestone, Marl & Shale	This Formation exhibits an overall progress in the degree of weathering. Forms landforms with terraces which are lower by one level than the bedrock zone described above.	No great danger of disaster due to its limited distribution. But, steep scarps may easily fail and generate small scale debris flow.	
Lower Cretaceous-Jurassic	JK^{ml}_{s}		Surmeh Fm.	Thick-bedded to massive Limestone with subordinate Marl	Because of occurrence along a narrow belt, only a few slope failures are seen.		

Table A-3(2) Summary Table of Geological Features Bazoft

Age	Geological map Legend	Classification Code	Stratum/Formation (Fm.)	Lithofacies/ Sediment Type	Mode of Occurrence and Distribution	Engineering Geological/Geotechnical Characteristics	Remarks
Quaternary Alluvium	Qal	Ri	River deposits	Gravel, sand, clay, silt	This formation was reworked resulting in partial development of debris flow. Also seen are the erosional features within the cultivated areas.		Ri and Fd were shown in the figure together as a new deposit.
		Fd	Fan deposits	Gravel with subrounded clasts (30~70cm in diameter) and sand-dominated material filling the space between clasts. Rather widely distributed along a river that drains across the central part of the investigation area from NW to SE.	Used for cultivation.		
	Dt	Dt	Detrital deposits	Distributed along the mountain slopes with structures that reflect the geological composition. Ubiquitous occurrence throughout the study area. Thickness is about 2~7m.	In general, there are no significant problems. However, casualties and damage to lives, cattles and houses in the past are known.	There are places, where the degree of risk is quite high. In particular, mountainside of the roads, road shoulder facing river and the abutments of bridges have undergone failures and scouring.	Based on natural disaster hazard survey data, this formation requires studies as early as possible.
		Ld	Landslide area (deposits)	Mixture of gravel and sandy soil/sediments	Small-scale landslides, several tens of meters in width, are seen in a small part.	It seems that reactivation occurred during snow-melting. But, direct damage due to this is almost nonexistent.	Landslide area was shown in the geologic map as a range.
Quaternary Diluvium	Q	Te-1	Lower terrace deposits	Gravel, sand, clay	Distributed as a belt along the main course of the river and the tributaries.	A part of this formation is affected by downward erosion. However, this are no significant problems.	As for the terrace, at least three steps are seen.
		Te-2	Middle terrace deposits	Gravel, sand, clay	Distributed as a belt along the main course of the river.	Part of it is affected by downward erosion but poses no significant problems.	
		Te-3	Higher terrace deposits	Gravel, sand, clay	Distributed as a belt along the main course of the river.	A part of this formation is affected by downward erosion. However, this are no significant problems. The scarps adjoining the road, mentioned above, are made up of this formation.	
Pliocene	Bk		Bakhtyari Fm.	Congromerate with sandstone	Bk is distributed in the top part of the mountain in the small scale		
Upper Miocene-Pliocene	Aj		Agha Jari Fm.	Red Sandstone & Marl	Occurs in the left bank of rivers that drain from NW to SE. Due to dominance of soft marl, the summit region exhibits gentle ridges. Serves as source for talus deposits.		
Miocene-Oligocene	As		Asmari Fm.	Thick to medium-bedded Limestone	Comparatively hard limestone is dominant.		
	Kn		Ashalary Fm.	Conglomerate	Kn is distributed in the northern part of the borderline within the small range.		
Paleocene-Miocene	Pb		Pabdeh Fm.	Shale , Marl & Limestone	Because of the predomination of soft rocks, surficial erosion and severe downstream erosion of areas adjoining the rivers, small scale failures are notable.	Though rock falls (including toppling of blocks) are seen, their occurrence is restricted to narrow zone and so do not pose serious problems. However, due to abundance of soft rocks, disruptions are seen in the landform.	
Eocene-Paleocene	Tz		Taleh Zang Fm.	Thick to medium-bedded creamy fossilliferous Limestone	In the investigation area, this formation has significant contribution to mountain body. Owing to the hard nature, the rocks form steep spurs and ravines.		
Upper Cretaceous	Sr		Sarvak Fm.	Alternation of bluish-gray Marl and Limestone	Distributed in the southern part of the investigation area. Soft rocks are dominant. Therefore, gully erosion at micro-scale is severely developed.		

Table A-3(3) Summary Table of Geological Feature Sarbaz

Age	Geological Map Legend	Classification Code	Stratum/Formation (Fm.)	Lithofacies/ Sediment Type	Mode of Occurrence and Distribution	Engineering Geological/Geotechnical Characteristics	Remarks
Quaternary Alluvium	Qal	Ri	River deposits	Gravels with rounded clasts (5~30 cm in diameter), sand, silt and clay			
		Al	Alluvium				
		Dt	Detrital Deposits	Gravels with subangular clasts (5~50 cm in diameter) and sand	Fall deposits, derived from the elevated parts of the mountain slopes, that differ in composition depending on the rock type or lithofacies occurring in the immediate vicinity. Poorly consolidated.	Wide development of small-scale landslides due to extraction of material from roadside, seepage of water from water canals and weakening of the formation due to snow-melting.	
	Q	Fd	Fan deposits	Gravels with subangular and subrounded clasts (3~10 cm in diameter) and clayey sediments	Small-scale occurrences near the confluences of the major river and its tributaries. They form gently sloping level surfaces that are suitable for farming.	*If the lower side is not invaded, it is unquestionable for Fan deposits*	
	Df	Df	Debris flow deposits	Limestone clasts (10~100 cm in diameter), subangular gravels, sub rounded gravels, and sandy clay fill	Accumulation of debris within steep scarps, which are 80~150m wide and up to several hundreds of meters long, in the southeastern end of the investigation area. They were formed several tens of years ago.	Rock slide within the ridges, in the upper reaches, serves as the source of debris. This debris, in turn, fails again giving rise to new tertiary deposits.	*There are ponds/lakes made by check dams in the* upper reaches of the river. Therefore, risk assessment surveys are necessary.
		Ld	Landslide deposits	Large, intermediate and small sized (5~10 cm) gravels and clayey sediments	They form mostly scarps. In marly areas, they occur along zones that are 20~50m wide and up to several *hundereds of meters long.*	Small scale landslides are numerous. However, in the absence of downstream gully erosion or extreme rainfall *events, they seem to be quiet stable.* An active landslide, (about 300 m wide, 60 m long) occurs in Kahangan village.	The landslide in Kahangan becomes active during periods of snow-melting. Also, there is somewhat large landslide along road joining Sarbaz. These two landslides require investigations.
Quaternary Diluvium	QT	Te-1	Lower terrace deposits	Sandy gravel and sandy soil occurring along the main river course	Along the river courses, they are deeply weathered such that they may undergo failure and subsequent erosion.	The collapse is seen in part in a region advanced by the invasion of the lower side	
		Te-2	Middle terrace deposits	Sandy gravel and sandy soil occurring along the main river course	Along the river courses, they are deeply weathered such that they may undergo failure and subsequent erosion.		
		Te-3	Higher Terrace deposits	Occurrences at small-scale within the higher parts of the slopes			
Eocene-Paleocene	Ja		Jahrum Fm.	Thick-bedded gray Dolomite	The surficial cover is eroded forming hilly landform; the muddy surfaces are widely cut by deep gullies.	This Formation covers most of the terraces. Because of the lack of any protective measures, the surficial layer is prone to erosion.	These inferences need confirmation.
Eocene-Paleocene	Kn		? Kashkan Fm.	Red conglomerate with Sandstone	Widely distributed within the uppermost part of the hilly landform. Upon severe weathering, the rocks disintegrate to sandy gravel. *In general, however, small* rock fragments or blocks are commonly seen.	Apparently, no problems.	
Eocene-Paleocene	Pb		PabdehFm.	Marl and Limestone, Shale	Pb is distributed vastry as hill geological feature in the *eastern part of region*	Pb is soft rock and wothering easily *The collapse along the river stands out*	
Upper Cretaceous	Pb-Gu		Gurpi Fm.	Alternation of bluish-gray Marl and Limestone	This formation is relatively weak. However, it has limited distribution.	Scarps are easily developed. This formation seems to be the source for debris (rock/sediment) flows.	
Cretaceous	Sv		Saravak Fm. Bangestan Group	Massive and brown gray Limestone	This formation occurs in most of the elevated parts of the ridges. Outcrops forming cliffs stand out amidst other types of soft rocks.		
Jurassic	Kgp		Surmeh Fm.	Limestone	This formation is distributed only in a small part of the investigation area.	no outcrop	
Cambrian	E		Zaigum Fm.	Well-bedded Shale	Crushed zones made up of shale formed along thrust faults are seen. They constitute large pass-like depressions in the uppermost parts of the mountains.	Numerous secondary faults are inferred within this formation. Weak zones seem to be common even in hard rock especially along fractures.	

Table A-3(4) Summary Table of Geological Feature Tang Sorkh

Age	Geological Map Legend	Classification Code	Stratum/Formation (Fm.)	Lithofacies/ Sediment Type	Mode of Occurrence and Distribution	Engineering Geological/Geotechnical Characteristics	Remarks
Quaternary Alluvium	Q	Ri	River deposits	Pebbly and cobbly gravel (clasts of 5~30 cm in diameter), sandy silt and clay	Distributed along current riverbeds; thickness is about 3~10 m.		Q contains three stratums of Ri, Df, Fd.
		Df	Debris flow deposits	Gravel with sub rounded to subangular clasts (30~80 diameter) with sandy sediments filling the voids	Derived from the rock-banked tributary at the upper reaches of the stream that serves as the water source for Tang Sorkh. These deposits occupy 30 m wide and 1500 m long zone. The debris mass is unstable. Cases of damage to human lives and cattles of nomads known.		
		Fd	Fan deposits	Gravels with sub rounded clasts (10~70 cm in diameter) and finer sediments	Deposited by tributary that flows through the middle of Tang Sorkh. At present, vegetation is present and the sites are stable.		
	DT	Dt	Detrital deposits	Gravel with subangular clasts (20~100 cm in diameter) and finer sediments.	Deposits derived by rockfalls from the higher parts of the slope. Therefore, their occurrence is controlled by the geology of the upper slopes. Sites dominated by either gravels or finer sediments are distinct.	Areas of occurrence of hard boulders/blocks of limestone are not problematic. In contrast, the areas constituted by limestone or strongly marly rocks forming cliffs collapse easily and cause damage to canals situated downstream. Also the latter sites are sources of debris flows.	This formation requires special attention. Important while selecting canal alignment, and appropriate construction method. The scarps along the right bank bank of the main river course may require stabilization.
Quaternary Diluvium	QT	Te-1	Lower terrace deposits	Pebbly to cobbly gravels (with clasts of 5~30 cm diameter) with sandy silt and clay	Occurs 1.5~2 m above the current river bed. Flat land used for farming.	Submerged under water during flooding.	Preparedness is required to fight the submergence.
		Te-2	Middle terrace deposits	In majority of cases, occurs as terrace formed by erosion of bedrock; gravel fill is present in certain part	Exhibits large rather flat or low relief topography. It is partially made up of sediments supplied by tributaries. Occasional remnants of sediments from the main river are seen. The surficial cover mainly consists of strongly weathered marl. In certain parts, remnants of hard rock form conspicuous hillocks.	Mostly used as agricultural land. The parts adjoining the major river course are being constantly eroded.	Protection of riverbanks is required.
Upper Pliocene	Bk		Bakhtyari Fm.	Conglomerate with Sandstone	Distributed in the summit region of the mountain body forming almost flat land or gentle slopes. Areas in the margins or those parts affected by dissolution by minor streams are subjected to progressive weathering resulting in conspicuous downslope movements.	Minor forests cover and pastures. Used for livestock grazing.	
Lower Miocene	Rz		Razak Fm.	Gray red Marl & Gypsum	This formation is conspicuous by the occurrence of numerous small-scale slope failures. It is distributed along a tributary flowing through Tang Sorkh (there are two branches in the upper reaches).	Presumably, the source of small scale debris flows ?	
Lower Miocene Upper Oligocene	As		Asmari Fm.	Thick to medium-bedded Limestone	Hard limestone. Outcrops as cliffs.		
Paleocene Upper Cretaceous	Pd-gu		Gurpi Fm.	Alternation of bluish-gray Marl & Limestone	Distributed forming hilly relief along the main river course, in remnant spurs and also gently dipping slopes. The middle terraces along the main river course are underlain by this formation.	This formation is extremely vulnerable to erosion.	
Upper Cretaceous	Sv		Sarvac Fm.	Massive Limestone	Occurs at the left bank of the main river course. In the upper part of the mountains, extensive exposures occur in the form of cliffs.	Rock boulders of 1~several meters linear dimension do occur. Though they are one of the causes of detrital deposits, no real problem is seen. The crown is used for animal grazing.	

Table A-3(5) Summary Table of Geological Feature Zeras

Age	Geological Map Legend	Classification Code	Stratum/Formation (Fm.)	Lithofacies/ Sediment Type	Mode of Occurrence and Distribution	Engineering Geological/Geotechnical Characteristics	Remarks
Quaternary Alluvium	Qal	Ri	River deposits	Gravel, sand, clay	Distributed along the main river course. The sediments constituting the floor of the tributaries are intermingled with talus/detrital deposits.		
		Al	Alluvium	Gravel, sand, clay	On temporary basis, check dams are made, the areas of deposition of pebbly to cobbly gravels and clayey sediments are leveled thereby creating agricultural fields.	No problem provided that there is enough supply of water. However, there are no springs and water is distributed through pipelines from the opposite of the river.	
	DT	Dt	Detrital deposits	Gravels with subangular clasts (5~10 cm in diameter) and clayey sediments	Distributed within the mountainslopes and floors of each tributary. The thickness within the riverbed is 20 m at maximum. Within the mountainslopes, areas dominated by detritus commonly exhibit slopes of over 30 degrees. Water is lacking and barren slopes are conspicuous.	Most part of the mountainslopes is covered by the detrital deposits. Their thickness is 3-10 m. Traces of quite large landslides are seen. As most countryside roads are constructed over excavated slopes covered by these deposits, there is a great danger of gully erosion.	This formation requires attention more than elsewhere. Although the existing road links villages which are seasonally uninhabited, proper protective measures are recommended.
		Ld	Landslide deposits	Gravel, sand, clay	Talus/scree deposits are very common. Accumulations at intermediate scale (over 100 m wide) have been confirmed at 5 places.	Although it seems generally stable at the present state, caution is required in case of severe downward erosion and heavy downpour.	Areas adjacent to the major roads require periodic inspection.
Quaternary Diluvium	Qt	Te-1	Lower terrace deposits	Gravel, sand, clay	Distributed within the narrow but long peneplanation surfaces along the main course of river.	Slope failures occur in areas with severe downward erosion.	
		Te-2	Middle terrace deposits	Gravel, sand, clay	Distributed within the narrow but long peneplanation surfaces along the main course of river.	Slope failures occur in areas with severe downward erosion.	
		Te-3	Higher terrace deposits	Gravel, sand, clay	Distributed within the narrow but long peneplanation surfaces along the main course of river.		
Upper Miocene	MPL^{sm}_{al}			Sandstone rich	distributed in the small scale extremely		
	MPL^{sm}_{a}		Aghajari Fm.	Red Sandstone and Marl	This formation contributes to over 90% of the area. The major constituent is marl with which sandstone layers of 3~8m thickness alternate roughly at 10m intervals. Compared to limestone, it has no water infiltration capacity. Therefore, problems of water storage are encountered during dry periods.	The bedrock itself easily weathers leading to widespread formation of cliffs throughout the area. Although the sandstone layer acts as a barrier suitable for preventing rock failures, the formation as a whole is extremely erodable.	Erosion is negligible in the presence of vegetation. The barren lands, however, are prone to gully erosion.
Miocene	Mg		Gachsaran Fm.	Gray and red Marl & Gypsum	Distributed within the belt along the main river course, from NW to SE in the eastern part of the study area. Within this formation, there are distinct collapses which occur in areas adjacent to the rivers.	The southern side is inaccessible due to occurrence of steep scarps.	
Paleocene-Eocene	Em^{dl}_{ja}		Jahrum and Asmari Fms.	Thick to medium-bedded Limestone	Occurrence at extremely small scale. Within this formation, large scale collapses occur in areas where these rocks occur close to the rivers.		

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ABBREVIATIONS

GIS	Geographic Information System
SPOT	Systeme Pour l'Observation de la Terre (Satellite Program begun by France)
NCC	National Cartographic Center
DEM	Digital Elevation Model
GCP	Ground Control Point
UTM	Universal Transverse Mercator

ANNEX B

GIS/DIGITAL GEOGRAPHICAL INFORMATION

B.1 Introduction of GIS

Geographic Information System (GIS) is the computer system to input, analyze, display and manage geographic related information. That is, GIS is implemented in order to manage and manipulate the spatial and non-spatial information, which is used for various kinds of study. In other words, GIS can play an important role to integrate the distributed spatial-related information among various organizations because of its database management function. Moreover, GIS can manage both spatial and non-spatial information in the same computer environment so that it would be one of the most powerful and useful tools to integrate water resources information in order to manage the watershed.

The GIS data preparation for the Study on Watershed Management Plan for Karoon River in the Republic of Iran was carried out by acquiring the various kinds of required data then organizing all in ARC/INFO data format by integrating them in a common coordinate system. Data were acquired by field survey, SPOT (Panchromatic) satellite imageries, interpretation of aerial photos, existing data such as topographic and others. The workflow is shown in Figure B-1-1. However, to provide data for the experts in their respective analysis in timely manner, some works especially that involved more time consuming, were produced in Japan. All the employed activities are discussed under following sub-headings:

(a) Interpretation of Aerial Photos
(b) Analysis of SPOT Satellite Imageries.
(c) Collection of Existing Data.
(d) Preparation of Skeleton (Background) Data for Maps.
(e) Preparation of Thematic Data for Maps.
(f) GIS Data Analysis.
(g) Output of Maps.

B.2 Interpretation of Aerial Photos

The aerial photographs at the scale of 1:40,000, covering the whole study area were acquired from National Cartographic Center (NCC). Those aerial photos for the study area were taken ranging from year 1991 to 1999 as shown in Figure B-2-1. All the aerial photos were interpreted for landslide and others. The landslide occurrence locations that were larger in area were delineated as polygon and those were too small, were marked as point.

B.3 Analysis of SPOT Satellite Imageries

All together 24 single scene SPOT satellite imageries covering the whole Karoon watershed area were used in this study. The Path/Row numbers and date of data acquisition are mentioned in Figure B-3-1. Due to the steep slopes in the study area, Digital Elevation Model (DEM) generated by GIS was employed to ortho-rectify the SPOT images to achieve more spatial accuracy.

(1) SPOT Image Checking and Printing
After acquiring the SPOT Panchromatic digital data, all were checked to confirm that those belonged to the correct area and have good quality. For clear visualization of different features, the necessary

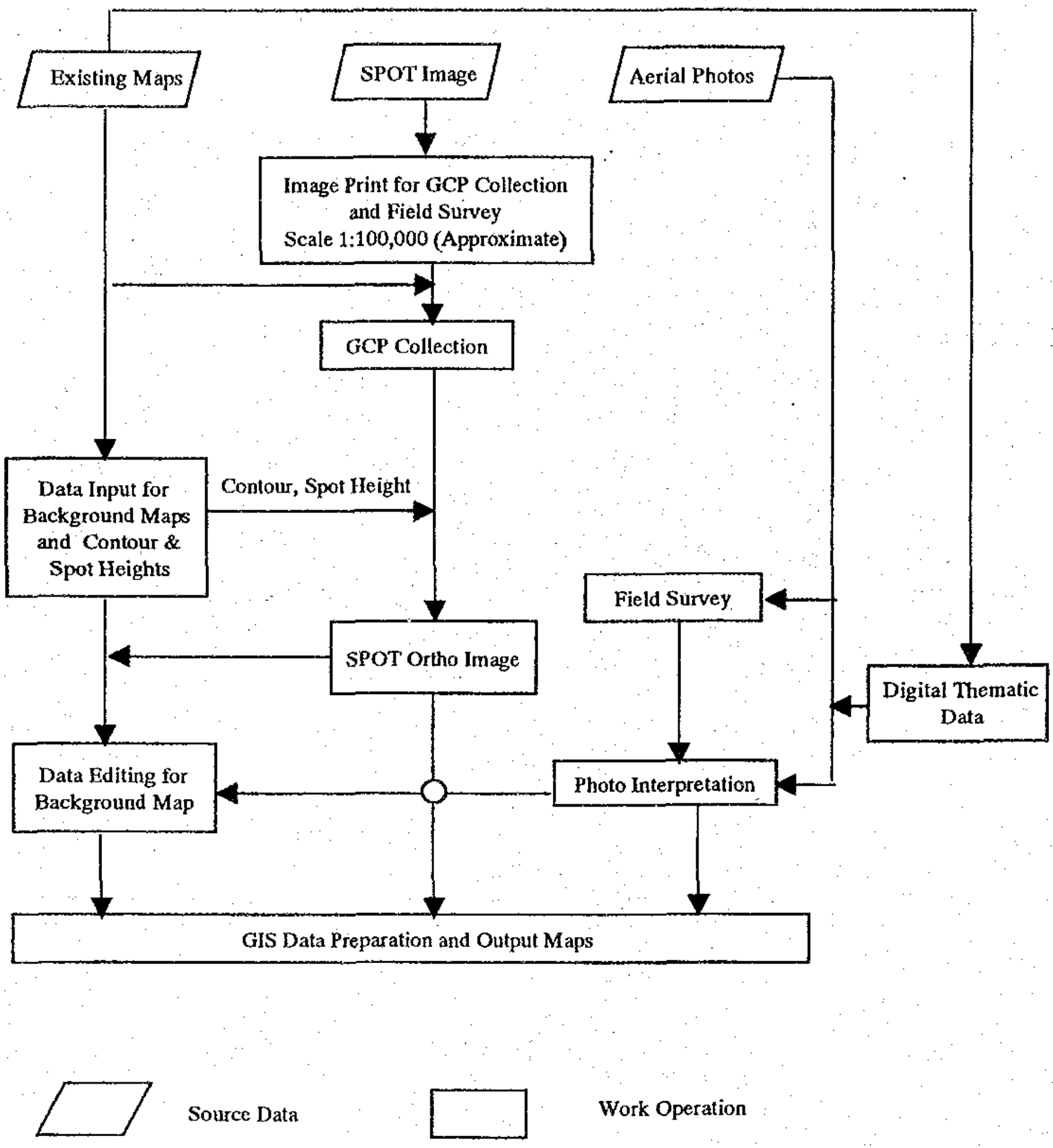


Figure B-1-1: GIS Data Preparation Work flow

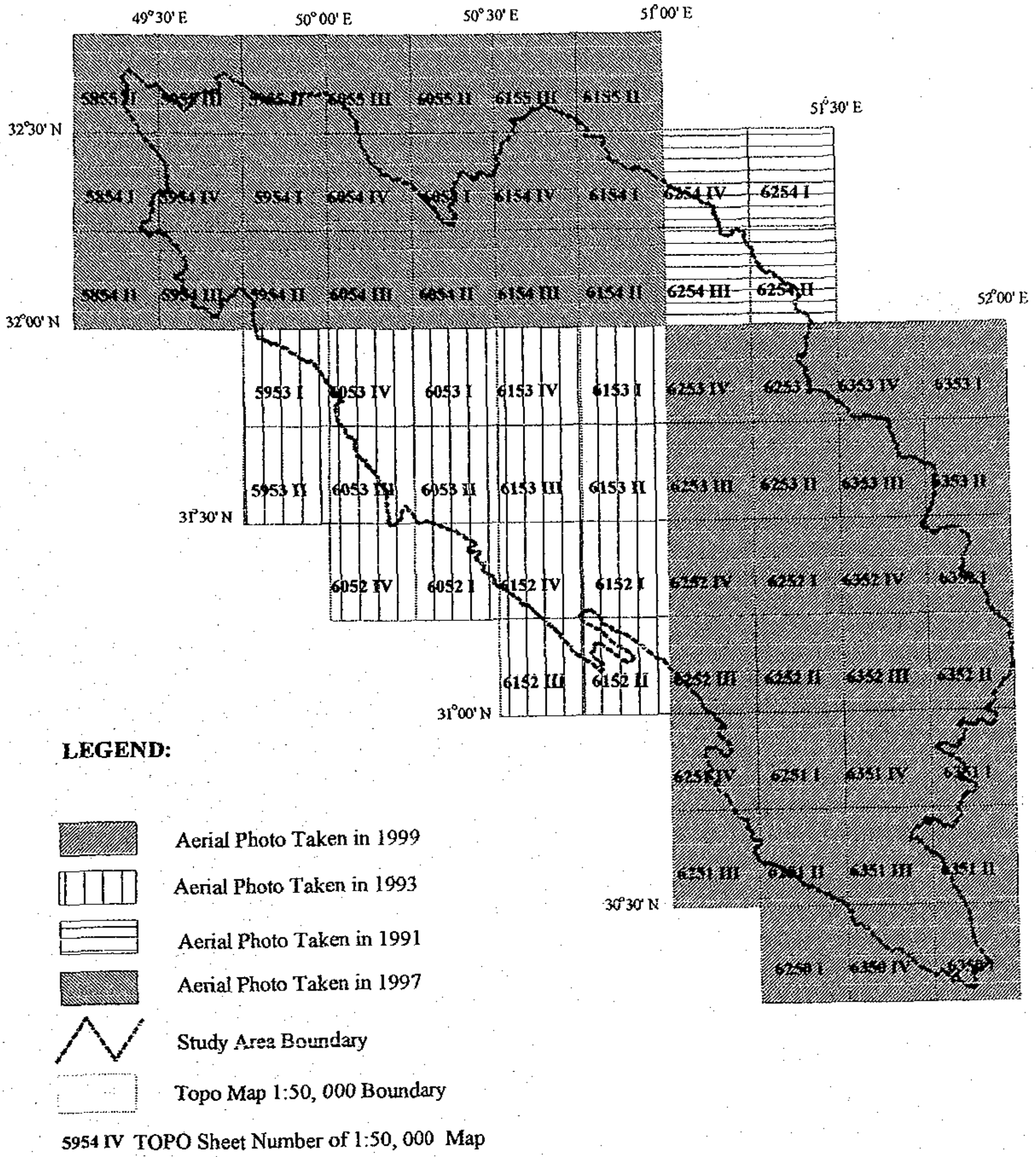


Figure B-2-1: Map Describing the Aerial Photos Acquisition Year

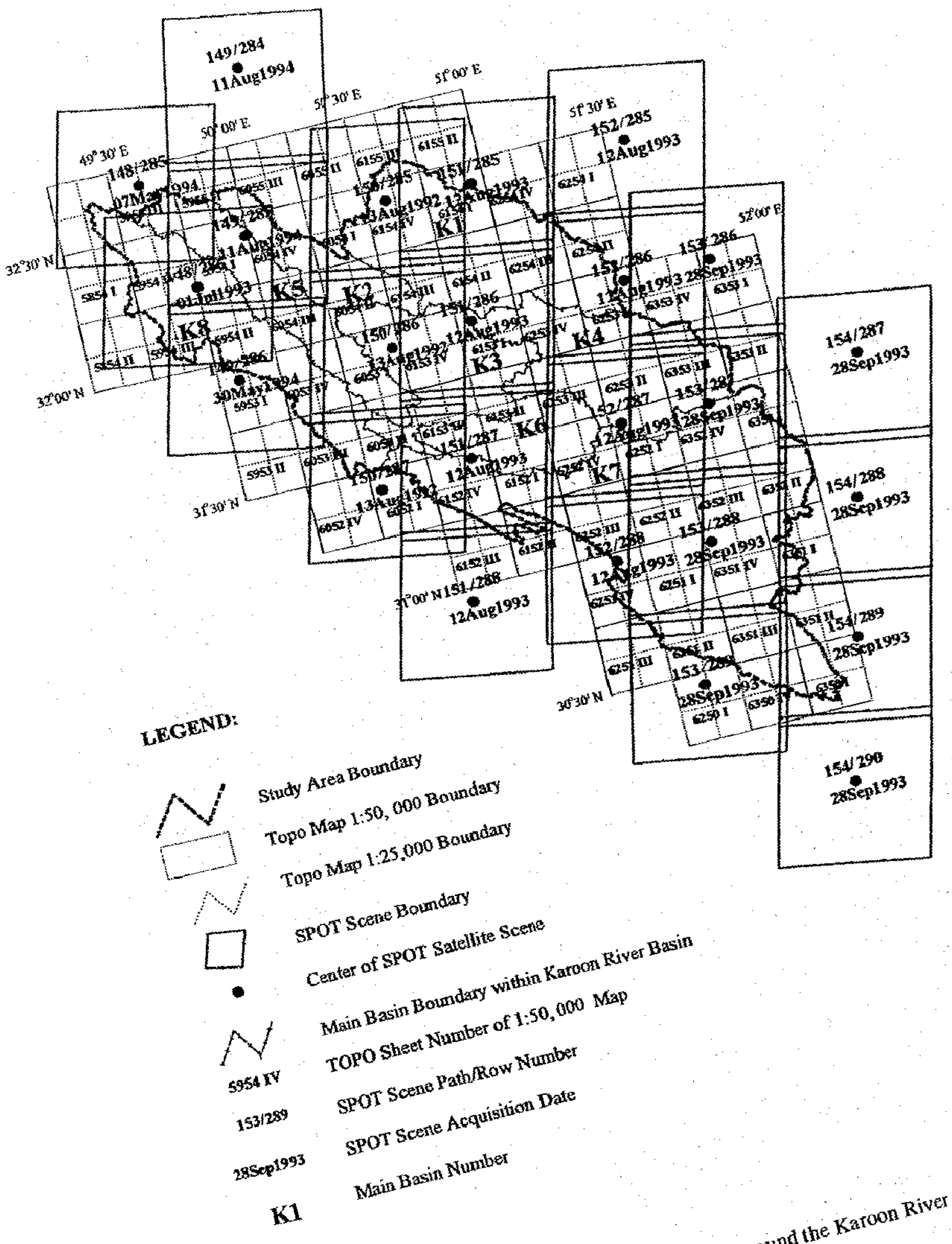


Figure B-3-1: Index Map of SPOT Scene Around the Karoon River Basin Area enhancement was applied to all SPOT data. Then, three kinds of images were printed at approximate scale of 1:100,000 to be used for GCPs collection and others.

(2) GCPs Collection
After collecting the existing 1:25,000 topographic digital data from NCC, GCPs referring to imageries and topographic data like road and river maps were collected. It was supplemented by necessary field survey data so conducted in the month of April.

(3) SPOT Ortho-images
DEM was generated from the contour lines and spot-heights. As mentioned in Figure B-3-2, DEM was created using TOPOGRID command under Arc/Info environment. For DEM, all the used input data were from 1:25,000 topographic data that collected from NCC except for very few area which was not available provided by NCC.

By inputting the collected GCPs and DEM, the SPOT images were ortho-rectified using Erdas Imagine software. Due care was given to input good GCPs in order to have better ortho-rectified image. As an example, the GCPs used for the rectification of SPOT scene Path/Row 152/287 is shown in Figure B-3-3. After applying the necessary enhancement for clear visualization of features, mosaicking and clipping, by the map sheet index were performed and the resulted ortho images were stored in GIS. These imageries were used to transfer the thematic information so delineated on the aerial photographs.

B.4 Collection of Existing Data

Basically the collected existing data were those required for background and thematic maps. These include relatively wide verities of exiting data, both in form of digital and paper maps as listed below:

(1) Topographic (1:50,000) maps
(2) Topographic (1:25,000) digital as well as paper maps

This includes information such as contour line (at interval of 20 meter), spot height, road, river, city, village, drainage network, lake, pond, forest, woods, bushland, rangeland, grape garden, orchard, park, cultivation, mine and so on.

(3) Administration data

This includes the administration boundaries like province boundary, township boundary, urban district boundary and rural district boundary.

(4) Land use data: maps (scale ranging from 1:100,000 to 1:250,000) and digital form
(5) Vegetation data: maps(scale ranging from 1:50,000 to 1:250,000) and digital form
(6) Land capability map (scale 1:250,000)
(7) Erosion sensibility data: maps (scale ranging from 100,000 to 1:250,000) and digital form
(8) Meteorological station data
(9) Gauging station data
(10)Dam location data
(11)Flood location data
(12)Protected area data and others.

B.5 Preparation of Skeleton (Background) Data for Maps

Skeleton data, capable of using as background for thematic map like vegetation and so on, was delineated. Following basic features are included for this purpose:

(a) Main and Sub-basin boundary: Those were delineated using 1:50,000 topographic maps.

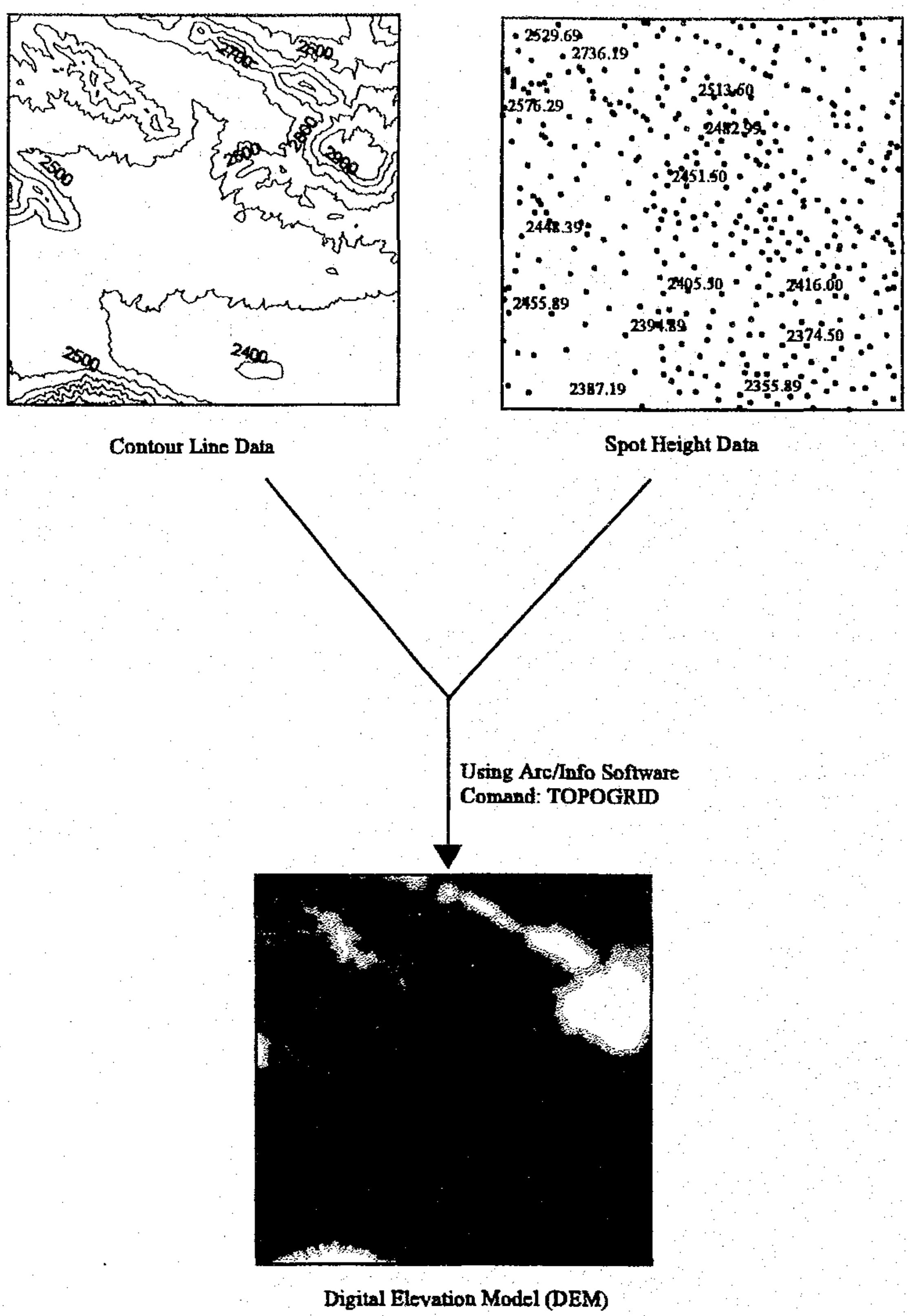


Figure B-3-2: Example Showing Methodology of DEM Creation

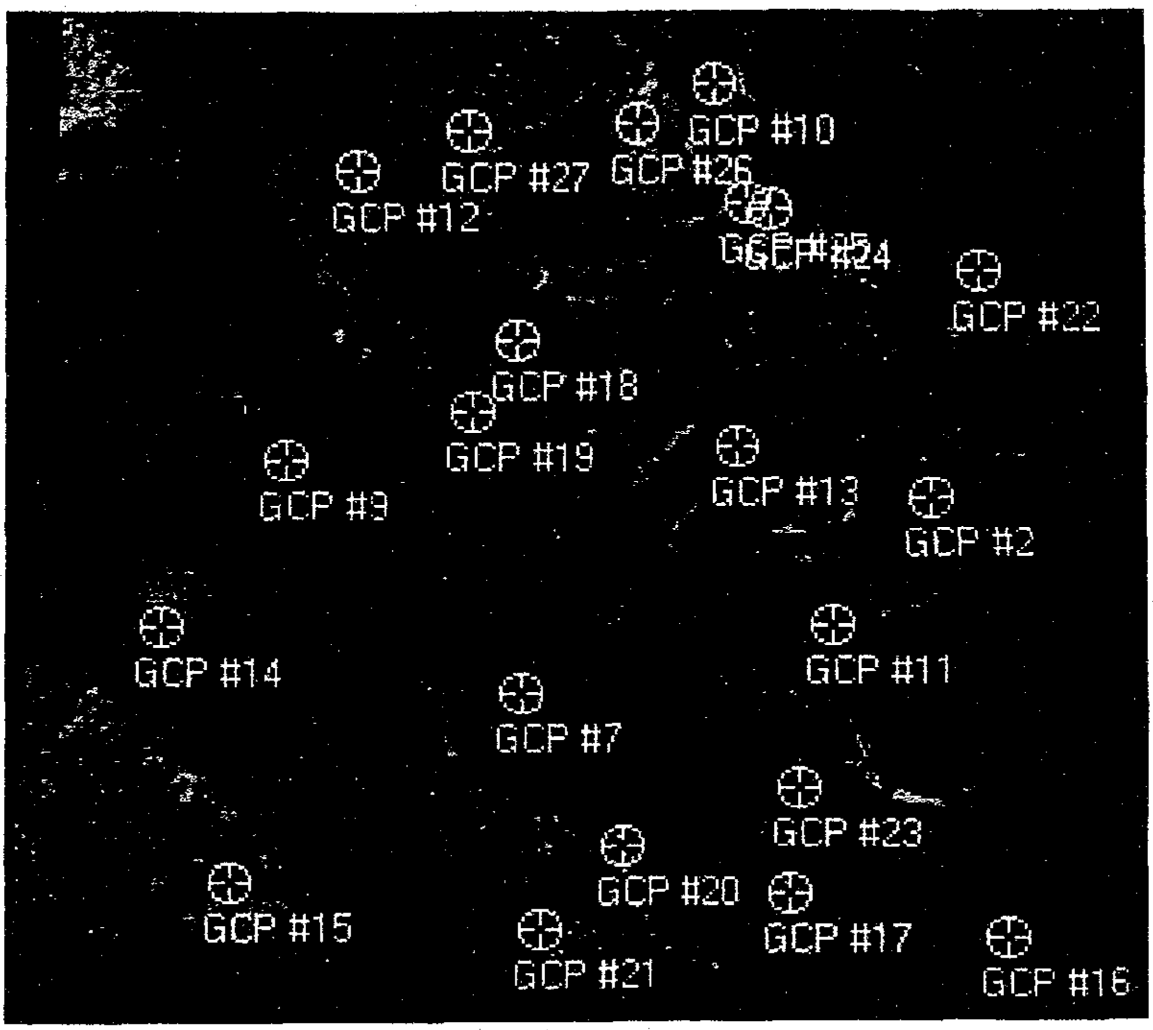


Figure B-3-3: Location of Included GCPs for SPOT Scene Path/Row 152/287

Altogether, 8 main basins and 455 sub-basins were delineated within Karoon River Basin (Figure B-5-1).

(b) Various kinds of roads: For most of area, road data was prepared from 1:25,000 topographic digital data of NCC and for the area lacking in that data set, was digitized from 1:50,000 topographic map. The digital data had 7 kinds of roads and to use these as background for 1:100,000 scale map, all were regrouped into two: Major roads and Minor roads.

(c) Major rivers: These were prepared from 1:25,000 topographic digital data of NCC. These were included as both polygon and line.

(d) Administration boundaries: These were prepared from the digital data received from NCC.

(e) Location of cities

(f) Lake/Reservoir

B.6 Preparation of Thematic Data for Maps

By combining the Interpretation as well as information from the existing maps, the following thematic layers were produced:

(a) Vegetation
(b) Land Use
(c) Erosion sensibility (erodibility)
(d) Land Capability
(e) Land slide
(f) Meteorological station location
(g) Gauging station location
(h) Dam location
(i) Flood location
(j) Protected areas

B.7 GIS Data Analysis

(1) Transferring all GIS data to a common coordinate system

In order to facilitate an accurate overlay of two or more GIS data together, all the GIS data so received from different source with different coordinate (projection) systems were converted to a common system. Most of background data used in GIS preparation being from the 1:25,000 topographic data of NCC, the selected parameters for the common coordinates for all the GIS data in this study were those that are included in the 1:25,000 topographic data of NCC which is as follows:

- Projection Universal Transverse Mercator (UTM)
- UTM Zone 39
- Unit meter
- Spheroid WGS84

(2) Overlaying of GIS data for cross area calculation

In this study, the basic unit of area calculation being at sub-basin, sub-basin data was overlaid with different thematic GIS data such as administration boundaries, vegetation, land use, erosion sensibility (erodibility), land capability, annual rainfall, mean maximum daily rainfall, and others. This kind of processing resulted the information about the aerial extent of various classes within a particular sub-basin. For example, the overlay of sub-basin with administration boundaries gave crystal clear information about which rural district with how much aerial extent is within a particular sub-basin. Moreover, the original rainfall information being at meteorological station level, was in point form and in order to overlay that with sub-basin data, it was first converted into polygon form using thissen polygon method.

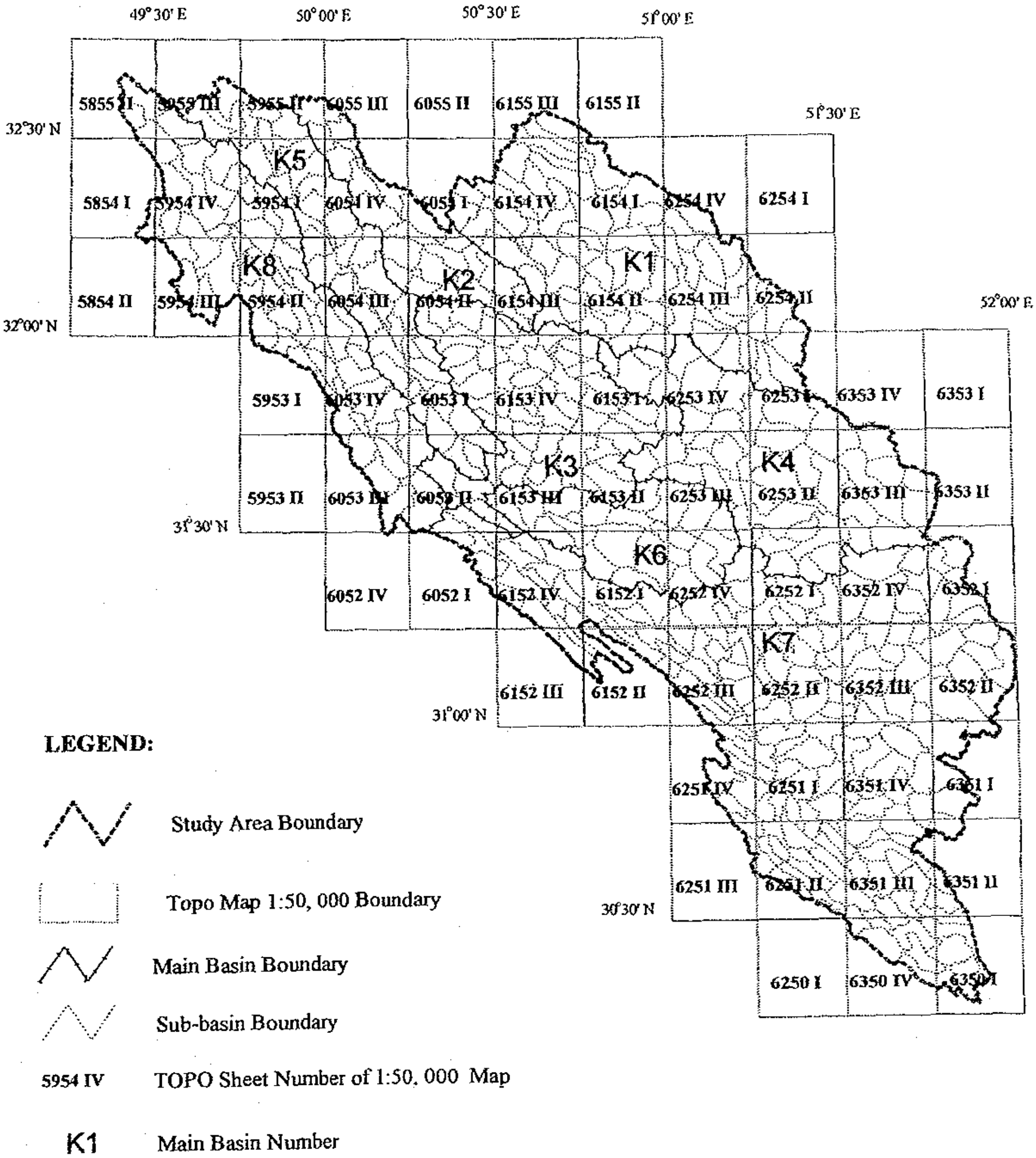
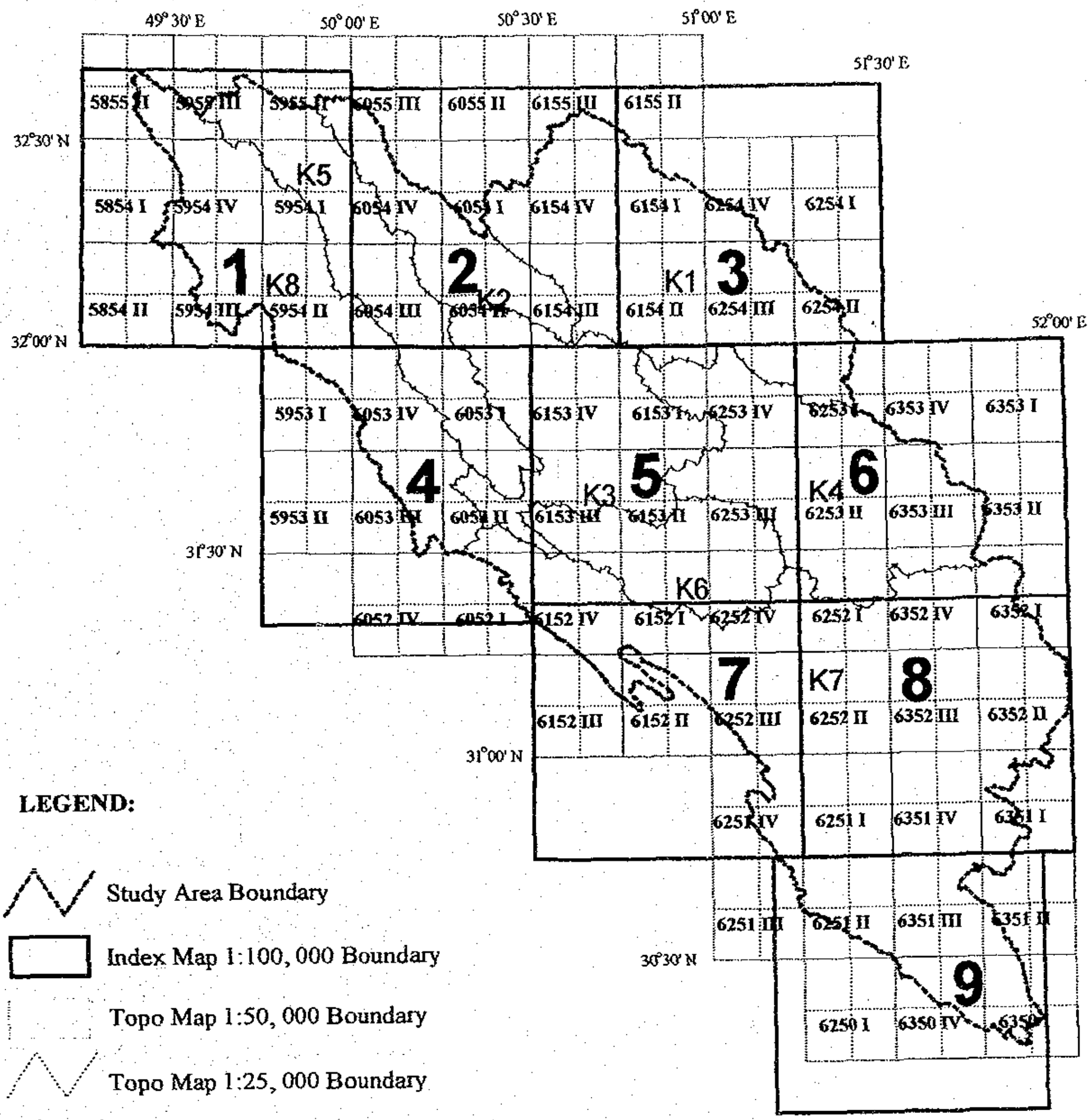


Figure B-5-1: Map Showing Main and Sub-basins in the Study Area

B.8 Output of Maps

(1) Index map
Based on 1:25,000 topographic map of NCC with the same coordinate systems as mentioned above, the index map for 1:100,000 scaled maps were prepared. As shown in Figure B-8-1, the whole study area was divided into 9 map sheets.

(2) Kinds of maps included.
Using the above Index Map, all the background data were overlaid first so that on its top, any one of the thematic layer could be overlaid titling map of that thematic layer. The thematic layers included were land slide, vegetation, land use, land capability, erosion sensibility and so on.



LEGEND:

Study Area Boundary

Index Map 1:100, 000 Boundary

Topo Map 1:50, 000 Boundary

Topo Map 1:25, 000 Boundary

Main Basin Boundary

5954 IV TOPO Sheet Number of 1:50, 000 Map

1 Serial Number of 1:100, 000 Index Map

K1 Main basin Number

Figure B-8-1: Index Map Sheet (1:100,000) Covering Whole Study Area for the Watershed Management Plan for Karoon River Project