CHAPTER II

GEOLOGICAL INFORMATION FOR LAND MANAGEMENT

2.1 Sphere of GILM Study (= Historical and concepts)

The significance of **"Geological Information for Land Management (GILM)"** were indicated as early as the 1890s when Kingsley, R.C. gave lecture regularly on **"Town Geology"** (Kingsley, 1887). And decade later, Ami,H.M. reported on the **"Geology of the Principal Cities of Canada"** (Ami, 1900).

The great progress of GILM works was in the mid 1960, concurrently with the use of the term **"Environmental Geology"** by Hackett in 1967. The works indicated a new orientation for study and use of geology in a broader applications. During that times, a number of publications of environmental geology and related subject such as, **"Urban Geology"** (Wayne, 1968); **"Environmental Geomorphology"** (Fairbridge, 1971); **"Cities and Geology"** (Legget, 1973); and **"Environmental Geoscience"** (Strahler and Strahler, 1973), were published and being widespread in Europe and North America. The number of publications are highly increased in the following decade later, and it is reasonable to call the period during 1970-1980 as **"the Environmental period"** (Coat, 1981). A number of valuable works to be mentioned are listed in the last topic of the previous chapter. These publications give valuable knowledge to those who want to apply the geological information to human activities encountered in land management.

In historical view, Marker and McCall (1989) mentioned that the initially practical GILM mapping has been firstly introduced by Pesak and Rybar (1961) and the works became appreciated in Europe from early the 1960s. The other pioneer works were published by Matula (1965, 1969), Echevarria (1967) and Luttig (1971). While in U.S.A., the multi-themes of GILM studies were published during the end of the 1960s, the pioneer works were published by Dubrovoly and Schmoll (1968) and Jacob (1971).

An important focal concept for land management occurred in 1969 when McHarg published the book **`Design with Nature'**. The book emphasized the important role of geology in planning. The method using plastic overlays developed to cover the subjects related to `Physiographic Constraints' (slope, drainage, bedrock geology and soils). They were designed in order to study their effect on planning. The work demonstrated how geology influenced in the planning process. (Marker and McCall,1989)

After the development of McHarg's method, the GILM became practically used. The method has been developed to produce multiple maps with variety of themes to serve multiapplications covering broad subjects of geological interest. Those important works credited by Marker and McCall (1989) are from Anould et al. (1980); Cendrero (1975,1986); De Beer et al. (1980), Doornkamp (1988); Foster (1986,1987); Ronai (1979); and Radbbruch-Hall (1987) and so on. The other example of GILM works collecting the number of works worthwhile to be recorded for further reference are: Tank (1973); Mckenzie and Utgard (1975); Frederick (1975); Utgard, Mekenzie, and Foley (1978); Davidson (1986); and Doornkamp (1988).

The result of investigation indicated that preparation of GILM are various, but all of them aim to assist in solving a practical problems to serve management activities. Recently, geological information become accepted and is required in several applications. For example, in view of a planner, McDonic (1987) noted that "... the need for geological information for planners was never so great as at present, and likewise the need to establish a working relationship between geologists and planners...". He also listed the information that the planner requires from the geologist that are :-

1) Basic identification of mineral resources, either for their immediate extraction or their safeguarding in the future.

2) Identification of geological hazards which may restrict land from being development.

3) Identification of key geological features that may merit conservation.

4) Information which establishes criteria for the classification of the value of land use or to be used for agriculture and forestry, the definition of land liable to flooding, the possible of serving an area with water and

sewerage, and the possibility of building stable roads, railways and pipeline routes.

Likewise the view of geologist, Valdiya (1987) defines the role of geologist in evaluating the suitability of the land on the basis of geological conditions. He determines the four major elements of a land management program are as follows.

1) In preparation of an inventory for land resources, make use of aerial photos and satellite images complementary to comprehensive fieldwork and then delineation on maps.

2) Identification of natural hazards likely to treat the area indicating the anticipated degree and frequency of the threats.

3) Investigation of various geomorphological, geological, hydrological, pedological and ecological properties of the land formulating a policy for landuse commensurate with the need of society.

4) Monitoring change that occur consequent on the use of land

According to previous works, it can be observed that GILM are broadly defined, and information presented on map are also prepared in various patterns depending on its circumstance and aim of works. The maps being prepared restrict to traditional map prepared for academic purposes, or application being constructed for each specific uses. So that, the map are named and classified according to its uses and to that particular field related, such as applied earthscience map, environmental geology map, geopotential map, thematic map, and constraint map etc.. Marker and McCall (1989) compiled all maps' names and conclusively explained as shown in table 2.1.

2.2 Study Procedure in Systemization of GILM

The procedure in study of systemization of GILM consists of 3 stages in consequently, which are shown with flowchart being illustrated in fig 2.1.

Firstly, to survey and study of GILM works; secondly, to identify framework concept of systemization; and thirdly, to formulate GILM system. The first two stages are discussed in the following sections, but the third stages will be discussed in chapter 3.

2.3 Surveys and Diagnosis of GILM Works Inventory

Systemization of GILM are explained in the book **"Earthscience Mapping for Planning and Conservation"**, published by Dr. Joceph McCall and Dr. Brian Marker (1989)

Accordingly, current status of geological information being used are concluded and demonstrated with some environmental geologic maps. The map topics are listed from various works being applied in the area of Europe and U.S.A. during 1969-1989. The total of 37 examples are studied, and are shown in table 2.2 with explanation and discussion.

Table 2.1 List of map and explanation defined after Marker and McCall (1989).

Name	Description
Applied earth science maps, geoscience maps, environmental geology map	Geological, geomorphological, hydrogeological, geochemical, geophysical and other maps, aimed at assisting in the solution of practical problem; usuallly presented as sets, sometimes with summary maps for specific purposes such as land use planning. The sets commonly include maps showing non-geological aspects and constraints.
Geopotential maps	Maps demonstraiting the resource and development potential of land
Engineering geology maps	A subset of applied earth science maps aimed a dealing with engineering problems
Thematic maps	Maps, earth science or otherwise, devoted to specific specialist topics
Element map	Thematic map showing observational or factual data on a single theme
Derived map	Interpretative map based on one or more element maps, synthesizing several types of information relevant to a single issue
Potential map	A category of derived map which demonstrates potential uses of land or the potential for processes to occur
Constraint map	A thematic map which shows the known extent and types of hazards in an area
Risk map	A map which attempts to quantify the likelihood of a damaging occurrence of given type and size
Resource map	A thematic map indicating the nature, extent and quality of resources on and under the ground

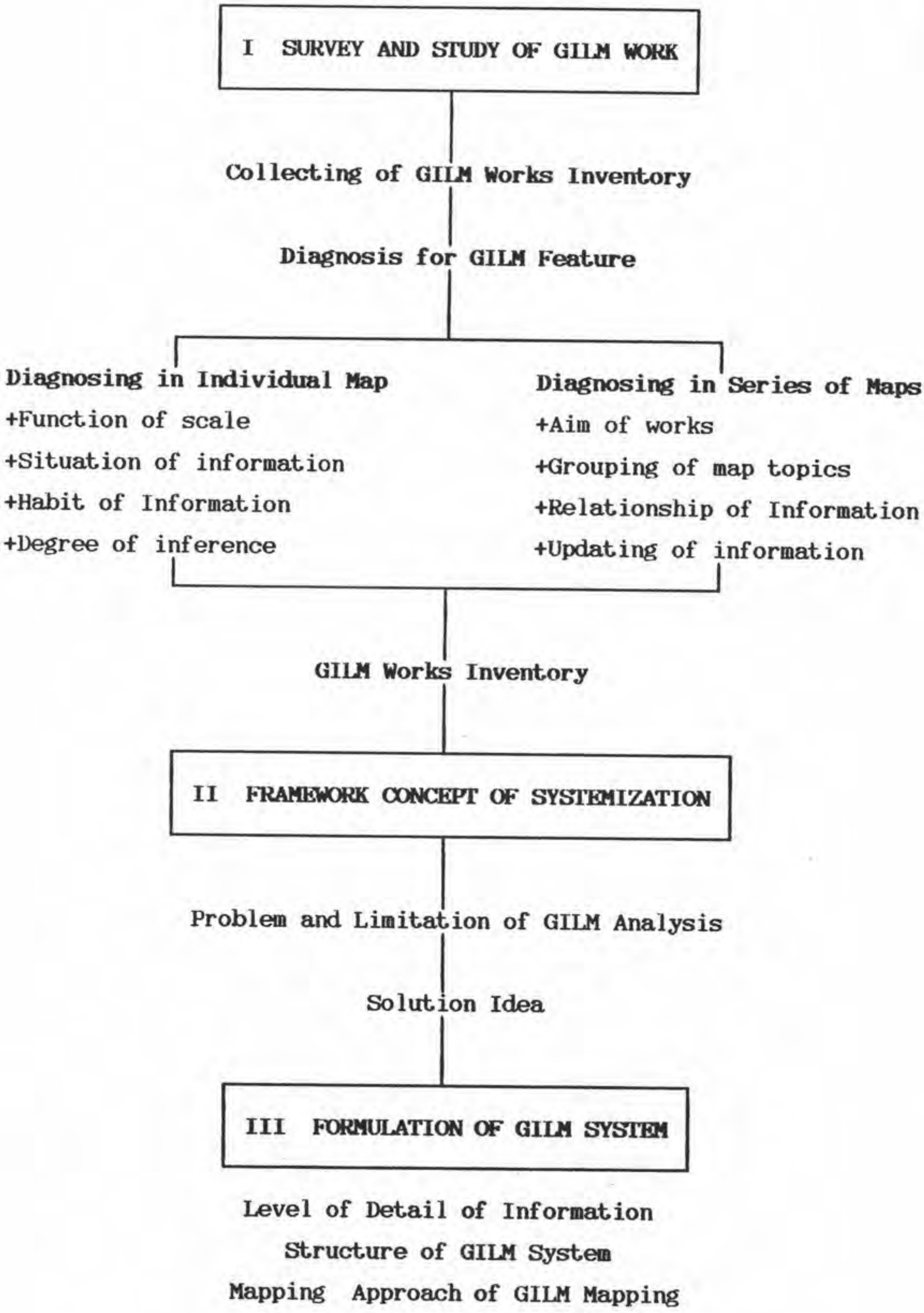


Figure 2.1 Flowchart illustrating systemization of geological information for land management (GILM).

Table 2.2 To illustrate form of Environmental Geology Mapping studies by Marker and McCall (1989).

Country	Area	Coverage	Scale	Map Topics	Description
UK	Upper Forth Estury, Scotland, UK (Gostelow & Browne, 1986	An area of 700km^2	1:50,000	**Element maps:** Drift thickness to rockhead Contours on the upper surface surface of glacial deposits Drift geology Distribution of mine working **Derived maps:** Engineering geology of solid rock. Engineering geology classification of soft sediments Geothechnical cross section **Potential map:** Geotechnical planning for heavy structures	Though termed and engineering geology study, this was very broadly designed and may reasonably be regarded as an Environmental Geology map study, with a strong constructional emphasis (heavy foundation). It is perhaps surprising that there is no detailed treatment of hydrogeology but it is stated that it is less important where deposits are concerned (and the study is primarily aimed at these). There is an interpretative (potential map) component. This study well illustrated the join between "Engineering and Environmental Geology Mapping" (multi-thematic) and the fact that the two are sematic terminological choices and in practice are overlapping and not distinctly separable.

This study of systemization of GILM is based on these examples together with those from other data sources. The total of 67 samples are studied. These are works being published during 30 years ago (1965-1994). The total of, 59 sample are prepared for practical works, 8 sample concerns with idea and concepts of GILM mapping. They are the examples from foreign country 51 samples, and the samples in Thailand 17 samples.

An aim in collecting of GILM works does not intend to demonstrate any statistic value, but to demonstrate the nature of information which are generally prepared for land management. The example of GILM works are shown in Table 2.3, and the whole collections are shown in Appendix 1.

Generally, GILM being prepared are illustrated with a map of multi-themes or in series or set of maps. They are differently prepared in pattern and form, and in number of map topics, according to each individual work and its objective.

In diagnosis of GILM features, they are observed in 2 ways. Firstly, to observe the nature or specific features of individual mapping themes of GILM. Secondly, to observe the overall features of GILM.

2.4 Diagnosis of individual maps

In observation of GILM, they are determined separately from each other according to 4 characters, the **"Function of Scale"; "Situation of Informations"; "Habit of Informations";**

Table 2.3 To illustrate form and pattern of file collection of GILM works of this research.

Source/location/coverage	GILM Topics & Themes	Sca	Sit	Hab	Deg	Series
Gostelow and Browne, 1986[1]	**Element maps:**					1) specific purpose.
	Drift thickness/depth to rockhead	m	a	t	l	(heavy structure planing)
Upper Forth Estury,	Contours on the upper surface of glacial	m	a	t	l	2) grouped by degree of infer.
An area of 35x20 km^2	deposits					3) 3 stage of relationship
Scotland	Drift geology	m	c	n	l	4) medium to high updatable
	Distribution of mine workings	m	d	t	l	
	Derived maps:					
	Engineering geology of solid rocks	m	a	t/n	m	
	Engineering geology classification of soft sediments	m	a	t/n	m	
	Geotechnical cross-section	m	a	-	m	
	Potential map:					
	Geotechnical planning for heavy structures	m	a	t	h	
Sunya Sarapirom, 1982[3]	**Physiographic setting**					1) multi purposes
	Climatology	s	o	t	l	2) grouped by mix.
Eastern Coast, Upper Gulf	Drainage	s	c	t	l	3) 2 stages of relationship
of Thailand	Geomorphology	s	a	n	l	4) low to medium updatable
	Slope	s	a	t	l	
Part of Eastern region of	Land use and land cover	s	o	t	l	
Thailand	**Geologic setting**					
	Mineral resource	s	a	t	l	
	Surficial deposit	s	a	t	l	
	Water resource	s	a	t	l	
	Marine geology	s	a	n	l	
	Development potential					
	Residential potential	s	a	t	h	
	Heavy industrial potential	s	a	t	h	
	Agricultural potential	s	a	t	h	

NOTE

Sources of data

[1] Studied from Marker and McCall(1989), [2] ; from rewrite papers, [3] ;from absolute report, [4] ; from proposed idea

Diagnosis features of individual maps

Sca-Function of scale : s=Small (<1:100,000), m=Medium (1:25,000-1:100,000), l=Large (1:10,000-1:25,000),

Sit-Situation of information : c=Classic, a=Applied geoscience, o=Non geoscience map, d=Data distribution

Hab-Habit of information : t=Thematic, n=Non thematic

Deg-Degree of inference : l=Low, m=Medium, h=High

Dignosis features of series of maps

1=Aim of works : Specific purposes, Multi-purposes

2=Grouping of map topics : Grouped by subjects, Grouped by degree of inference, Grouped by both of subjects and Degree Inference, or non-significant of grouping of maps

3=Relationship of information : 2 , 3 , 4 stages of relationship, non significant of relationship of maps.

4=Updating of information : Low, Medium, or high updatable

and "Degree of Inference". The conclusive result of diagnosis are concluded and illustrated in table 2.4.

2.4.1 Function of Scale

The scales of GILM in individual maps ranges between 1:5,000-1:7,000,000 scale. This is depend on detail of informations to be demonstrated for that particular maps. Observation can be concluded as follows:

1) There are no GILM be prepared in the scale larger than 1:5,000. (Work that need information in detail at the scale of 1:2,000-1:5,000 are grouped in "site plan", and this would not be grouped in the field of GILM (Marker and McCall, 1988))

2) The relationship of map topics and scale cannot be definitely concluded, however, they are observed as follow :-

2.1) The GILM investigation of medium to small scale maps (1:25,000-1:100,000), it is observed that they are used in most of topics in basic geological information maps. They are bedrock and superficial deposit map, soil map, drainage map, slope map, hydrogeological map, hazard map, resource map, slope stability map, etc.. Maps of these scale are also found being used to illustrate suitability area for land development. Maps of these scale are found commonly used in tradition or standard GILM maps.

2.2) GILM of large to medium scale maps (> 1:25,000), it is observed that data required for maps preparation shall be derived from field survey or laboratory. These general themes are comprised of detail lithological map (solid/drift

Table 2.4 To illustrates some of diagnosis features in individual maps.

Topics	Sca	Sit	Hab	Dei	Topics	Sca	Sit	Hab	DeI
Active fault zone/locations map	s-m	a	t	l	Fault/fracture map	s-m	c	t	l
Aquifer map	s-l	a	t	l	Metamorphism zoning map	s-m	c	t	l
Basic geologic map	s-m	c	n	l	Mineral resource quality map	s-l	a	t	m
Capacity to accept waste area/site map	m-l	a	t	m	Physiographic units (types) map	m-l	c	t	l
Cost for reclaimation map	m-l	a	t	m	Potential of water supply area map	s-l	a	t	m
Cost of engineering works map	m-l	a	t	m	Quality of water and precipitation	s-l	a-o	t	m-l
Dept of bedrock map	m-l	c	t	l	Risk of hazard map	s-l	a	t-n	m
Drainage system map	s-m	c	t	l	Rockmass/outcrop (bedrock) material map	s-l	c-a	t	l
Engineering geological map	m-l	a	t-n	m-l	Selected civil engineering works coridors map	s-l	a	t	h
Geoheritage site value map	s-m	a	t	m	Slope map	m-l	a	t	l
Geohydrological map	s-m	c	n	l	Soil map	s-m	c	n	l
Geomorphological map	s-l	c	n	l	Stratigraphic map (litho-/bio-/chrono-)	s-l	c	t	l
Geoscience heritage site map	s-l	a	t	l	Subsidence susceptibility map	s-l	a	t	m
Geotechnical properties map	l-l	a	t-n	m-l	Suitability zone/area/site for geological	s-l	a	t	h
Groundwater rechart area (strata) map	s-l	a	t	l-m	resources developement				
Groundwater flowing direction map	s-l	c	t	l	Suitability zone/area/site for	s-l	a	t	h
Groundwater flowing rate map	s-l	c	t	l	(active/passive) recreation				
Groundwater level and yield map	s-l	c	n	l	Suitability zone/area/site for agriculture	s-l	a	t	h
Groundwater chemical properties map	s-l	a	t	l	development/conservation				
Groundwater quality/quanity map	s-l	a	t	m	Suitability zone/area/site for land	s-l	a	t	h
Hypsometric map	s-l	c-o	t	l	development/build up area				
Land pollution susceptibility map	s-l	a	t	m	Superficial (surface) material map	s-m	c-a	t	l
Land/slope stability map	s-l	a	t	m	Surface drainage runoff rate map	s-l	a	t	l
Landform units (types) map	s-l	a-c	t	l	Surface processes map	s-l	a	t	l
Landuse and land cover map	s-l	o	n	l	Top soil thickness map	m-l	c	t	l
Lithological map	m-l	a-c	t	l	Watertable rise condition map	s-l	a	t-n	l

* The explanation of abbrevation can be used together with table 2.3 (p.21)

edition), depth of bedrock or topsoil thickness map, depth of groundwater map, geotechnical properties of material maps and the suitability site for specific projects such as sanitary landfill map, etc..

3) The relationship of the level of scale and area coverage would be different in the level of scale which mostly related to the area coverage of land management purposes. These can be divided into 3 levels as follow:

3.1) Level of small scale or synoptic scale is commonly the scale smaller than 1:100,000. Purpose of works commonly would cover large area and aim to overall management. From the collection of works, this scale level commonly produced GILM in level of province, large metropolitan area, large county area, or in large region of geography. For example, the works from Cendrero (1987), Ronai (1979), Tonies (1987), Montri Choowong (1992), Nikorn Mungkung (1992), and Luksamee Jeawechasin (1992), are operated to cover province area; Chaiyudh Khanthaprab and Niwat Boonnop (1988) operate to cover the metropolitan area; Crosby (1978) works to cover large county area; Helly (1979), Radbrush-Hall (1979), and Sunya Sarapirom (1982,1992) work to cover large geographic region, approximately larger than 1,000 km2.

3.2) Level of medium scale, commonly range between the approximate scale of 1:25,000-1:50,000. Works are prepared to cover the smaller area and have more specific purpose. The coverage area is usually county area or any specific landuse area such as in urban area. For example, the several works of Atwater (1978), Brigg (1977), Geomorphological service Ltd. (1986), Gonzalez (1977), and Matula (1980), all of them cover the area of one county or district; the several works of

Mazeus and Monza (1979) cover urban area ; and the example of Nickless et al. (1982), Tinakorn Ta-Thong (1994) which used the size of the topographic map sheet (scale 1:50,000). The coverage area is approximated between 1,000-10 km2).

3.3) Level of large scale is commonly the scale approximate 1:10,000 and larger. Purpose of works to cover small area with certain specific aim of management. For example, the several works of Chritensen (1979) cover part of county area; Floyed (1982) worked to cover area in the southeast of city; Foster (1982) worked to cover small area of the city; Froclich (1982) worked to cover urban community; Gardner and Johnson (1978) worked to cover subdivision of small hillside; Langu and Johnson worked to cover small township; and Wilson and Smith (1985) worked to cover small urban area. The coverage area is approximated less than 10 km^2.

The results of observations from diagnosis of function of scale are shown in table 2.5.

2.4.2 Situation of Information

The nature of geological information being prepared for GILM are observed. Some of them are prepared for specific uses and only users who are trained geologists can understand. While the others are prepared to serve general application. The situation of GILM can considered into 2 groups which are the group of classic geoscience maps, and the group of applied geoscience maps.

Table 2.5 To illustrate result of observation in the Function of Scale with Map Topics and Area Coverages.

Map Topics/ Area Coverages	Site Plan (>1:5,000)	Large Scale (1:5,000-1:25,000)	Medium Scale (1:25,000-1:50,000)	Small Scale (1:100,000)
Example of specific Map Topics in different function of scales	Not be grouped in the field of land management	The specific topics which be required of detail fieldwords and laboratory studies such as Detail lithological map, depth of bedrock map, depth of groundwater map, geotechnical properties of rockmass and superficial maps, suitable site/area selected for specific projects, etc... (can be extended to medium scale level)	General topics such as Basic geologic map, Bedrock and superficial deposite map, soil map, geohydrologic map, sloe map, hazard map, resources map, slope stability map, drainage map, suitable zone or area for general landuse activities, etc...	
Example of level of treatment in different function of scales	Not be grouped in the field of land management	To treat for level of small area such as A part of county area, A part of city, Urban community area, Subdivision of small hillside, Small township, etc...	To treat for level of medium area such as level of County area, Urban area, District, Size of standard topographic map sheet in scale 1:50,000, etc...	To treat for level of large area such as level of Province , Large county area, Large region of geography, etc. .

a) Classic Geoscience Maps

The most common geological informations which are generally available, are published in "geological map", "hydrogeological map", "soil map" and etc. They are basic GILM map that can be grouped as "classic" or "traditional" geoscience maps. They are prepared for the benefit of mineral resources exploration, development of groundwater resources and agriculture planning. The other maps which belong to this group but not commonly available is for an example "geomorphological map" which show landform and process, surficial deposit, and chronology of terrain evolution. This kind of map has it nature vary to its objectives. However, the geomorphological map would have amount of informations being necessarily used in the field of land management. The other groups of maps such a "structure geological map" which show structural geologic features such as folding, faulting, fractures and tectonics condition of earth crust, and "metamorphic map" which show metamorphic zone of rock facies etc. These maps are prepared only for specific uses for geologists in that specific fields. They are not easy to be understood by those who has no geological background.

b) Applied Geoscience Map

The geological information map which are prepared for uses in the field of land management, were called as "applied geoscience maps", "applied earthscience maps" (Marker and McCall, 1989). They are resources aspect such as mineral resource map, fossil fuel map, construction material map etc.. These illustrate distribution, potential or suitability for exploitation. The other grouped devote to hazard aspect which illustrating for location, area coverage, and susceptibility or risk degree. The applied geosciences commonly has simple form and presentation, showing the specific informations of each themes in habit of the "thematic map". These purview include also the maps illustrating the geotechnical properties in several themes as strength, permeability, shrink and swell properties, ease of excavation, slope stability, etc.. Thus, applied geoscience maps are a development of illustrating informations to facilitate and efficiently uses in analysis in land management strategy. In some aspect, for example " engineering geological map", the information had been produced especially for civil, mining and environmental engineering works. The "environmental geological map" are used in environmental management or environmental impact assessment (EIA). Marker and McCall (1989), made statement that "the term 'environmental geology mapping' has been used in many senses. It has been used both for studies covering only a few themes and for research incorporating sets of a dozen or more map addressing a broad spectrum of earth science (and sometime other) interests. The term 'engineering geology mapping' has been treated sometimes as a synonym of environmental geology mapping. Although, engineering uses are only one section of the total span of interests which have been covered in such studies."

Table 2.6 illustrate the example of map topics in both of situations.

Besides, in table 2.1 has shown description of some name used in conjunction with applied earthscience mapping. It can

Table 2.6 To illustrate examples of map topics in the situation of classic geoscience information and applied geoscience information.

Example of Map Topic in the Situation of Classic Geoscience Information	Example of Map Topics in Situation of Applied Geoscience Information
Geological map	Geological resource map
Geohydrological map	* mineral and fossil fuel
Soil map	* construction material
Geomorphological map	* earthfill
Structure geologic map	Geological hazard
Metamorphic map	* flooding
etc.	* landslide
	* earthquake
	* erosion
	etc.
	Engineering geologic map
	Strength of material map
	Shrink and swell properties of material map
	Ease of excavation map
	Slope and slope instability map
	Environmental Geology map

be observed that the geological informations are produced to serve only to users who are the planner or manager in specific objective of land management rather than to serve for general uses. Beside that, there are maps prepared from direct observation called "element map" and also those maps illustrate geological information prepared from processing of factual data. They are termed "derive map", and "constraint map".

2.4.3 Habit of Information

It is observed that GILM maps are prepared in 2 characteristics of habit, thematic map and non-thematic map. The Thematic map is prepared to demonstrate specific topic of information in one map, such as slope map and lithological map. For non-thematic map is prepared for one subject demonstrating with several related topics of information within one map. For example, geological map demonstrates stratigraphic units together with structural features and mineral deposits. The example of map topics in thematic and non-thematic habits are shown in table 2.7.

2.4.4 Degree of Inference

GILM in each theme have different degree of inference. There are three different in nature of information to be observed according to its sources.

Firstly, they are information prepared from direct observation, or factual data of geological features;

Table 2.7 To illustrate examples of map topics and their possible detail of informations in Thematic and Non-thematic habits of maps.

Thematic		Non-thematic	
Map Topics	Possible Detail of Informations	Map Topics	Possible Detail of Informations
Lithologic map of rockmass	Distribution of lithologic unit of rockmass/outcrop	Geologic map	Distribution of stratigraphic units, their structure as fold, fault, fracture, tectonics movement direction, some are include of mineral occurence, mine location.
Fracture map	Distribution of fracture structure		
Mineral quality distribution map	Distribution of particular areas which different of mineral deposits quality	Geomorphological map	Distribution of landform units, morphographic features, surface materials, chronologic data of terrain evaluation, drainage and surface process of areas.
Mineral resource potential map	Distribution of particular areas which different of potential for mining		
Slope map	Gradient of land in particular area	Engineering Geologic map	Distribution of geotechnical properties of material, generally as strength, Liquifaction expasive condition, seismic response slope stability and other ground problems.
Landform map	Distribution of landform units		
Drainage map	Drainage features of area	Environmental Geologic map	Area of geologic hazard, locations of construction materials, groundwater condition , some are add up by non-geologic data as national park area, urban area or other landuse and landcover.
Morphographic map	Showing shape and configulation of land by different symbol		
Strength of material map	Relative strength properties of materal in particular area		
Slope stability map	Relative stability or susceptible to failure of slope		
Area of potential development of groundwater etc.	Relative potential of groundwater resource of particular area		

Secondly, they are information prepared from interpreting or analyzing process and be indicated with technical value;

Thirdly, they are information prepared from evaluating process indicating with it suitability in particular landuse.

These three differences in nature of information have different degree of inference which can be classified into three orders as the followings:

1) Geological information on low degree of inference:they are informations derived from direct observation. They are illustrated on map showing the factual geological data such as landform, rock types, soil types, structure, mineral deposits, location and geohydrological data, etc. In general, the maps of this nature have more detail of information than the maps belongs to higher degree of inference.

2) Geological information of medium degree of inference:they are information derived from interpretation and/or analysis from factual data. They are indicated with comparative value of geotechnical properties, susceptibility or risk and/or potential of events and/or result of geological process such as risk of flood hazard, erosion or deposition susceptibility. They are normally illustrating a comparative value for that particular works. In general, they are presented in simple and uncomplicate way in order to facilitate users.

3) Geological information of high degree of inference: they are information illustrating with a comparative value of suitability in that particular activities. These information is derived from synthesis of the one or more maps of the lower degree. Commonly, geological information of this groups are presented in simple way to facilitate planners who are not geologist.

Table 2.8 illustrates example of map topics in difference of degree of inference.

2.5 Diagnosis of Series of GILM maps

In diagnosis of series of GILM works, sets of map topics are investigated. They are observed according to the aim of works, grouping of map topics, relationship of informations, and updating of information.

2.5.1 Aim of Works

Aim of works could be diagnosed from the subject of map topics with in a series. Observation can be considered into 2 groups. The one was the series produced for single specific purpose, another one is for multi-purposes.

In case of specific purposed, they are for example: Atwater (1978) produced series of maps for Earthquake hazard planning; Brigg (1977) studied for hazard aspect; Cleaves et al. (1974) studied to serve about mining management; Devidson (1978) worked for mine effect urban studied; Froelich et al. (1978) studied for housing development planning; Gostelow and

Table 2.8 To illustrate examples of map topics in difference of degree of inference.

Low Degree of Inference	Medium Degree of Inference	High Degree of Inference
Geological map	Landslide susceptibility	Urban suitability
Soil map	Risk of potential erosion	Zone of suitability for development
Geomorphologic map	Risk flooding	Commercial industrial suitability
Geohydrologic map	Subsidence potential	Geotechnical planning for heavy structure
Depth of bedrock map	Difficulty of excavation	
Depth of water table map	Drainage treatment cost surface	Land suitability for housing area map
Lithology and facies map	Risk of coastal erosion	
Slope map	Slope stability map	
Distribution of mine working	Soil susceptible to frost	Recommendation for regional planning
Borehole site	Natural landslip potential	
Topographic map	Possibility of floodprone area	Recommendation for landuse
Area of erosion	Potential fluid wast disposal	Specific area of landuse potential
Construction material site map	Potential Earthquake damage building	Suitability for agriculture
Mineral distribution map	Earthquake risk map	
Earthquake location		

Browne (1978) studied for heavy structure planning; Sunya Sarapirom (1992) studied for road corridors; Surachai Sompadung (1992) studied for the work in disposal area, residential area, and commercial area development.

In case of multi-purposes, the examples are the works from McHarg (1969), Montgomery (1969), Floyd et al. (1982), Freeman Fox Ltd. (1987), Geomorphological Service Ltd. (1988), Mckenzies and Utgard (1975), Nickless (1982), Nikorn Mungkung (1992), US.geological survey and Department of Housing and Urban development (1978), and Wilson and Smith (1985).

2.5.2 Grouping of Map Topics

Each of GILM works have different grouping of map topics in each series of works. Observation can be considered into 3 modes. They are : grouping by subject; grouping by degree of inference; and grouping by both of subjects and degree of inference. However, there are several works which have no significant characteristics to be grouped.

1) Grouping by subjects: they are groups of map topics belong to the subjects being subdisplinary of geology. For example, there are groups of map topics fall in Geomorphology group, Earth material group, Engineering properties group, Geological resources group, Geological hazard group, etc. The grouping by subjects appeared in the works of Brigg (1977), Chaiyudh Khantaprab and Niwat Boonnop (1988), Edward (1987), Helley and Lajoie (1979), Jacob (1971) and St-Onge et al. (1975).

2) Grouping by degree of inference: they are groups of map topics being prepared from factual data, interpretative and analysis data, or evaluative data. In example, the theme which have low degree of inference are categorized to be basic map or element map. The theme which have medium degree of inference are categorized to be derive map, interpretative map, value map, or capability map. The themes which have high degree of inference are categorized to be potential map, suitability map, or planning map. The example of works which be prepared according to this features are Floyd (1982), Freeman Fox Ltd. (1987), Geomorphological Services Ltd. (1988), Gostelow and Brown (1986), McHarg (1969), Mckenzies and Utgard (1975), Sunya Sarapirom (1992), U.S.Geological Survey and Department of Housing and Urban Development (1978), Williams (1983), and Wilson and Smith (1985).

3) Grouping by both of subjects and degree of inference: they are groups of map topics having mix characteristics, these appeared in the works of Cargo and Mollory (1977), Gardner and Johnson (1978), Montgomery (1969), Sanya Sarapirom (1982), and Tanawat Jarupongsakul (1992)

Table 2.9 illustrate the example of GILM works fall in different grouping of map topics.

2.5.3 Relationship of maps

Relationship of information is the feature of the relevance or connecting between maps within the series which be considered in depend on their together. Table 2.10 illustrate the examples of GILM works which have different in

Table 2.9 To illustrate sample of GILM works which are different in grouping of map topics.

Sorces/location/coverage	GILM Topics & Themes	Sca	Sit	Hab	Deg	Series
Tinakorn Tathong, 1994[3] Ban Na Si Thang, Had Yai Full of Map sheet 5023 II, 5023 III	**Environmental Geology**					1) ? 2)non significant of grouping of maps'topics 3)non significant of relationship of maps (2 stages?, by expected) 4)low updatable
	Geological resource potential	m	a	t	m	
	Industrial Rock	m	a	t	m	
	Construction Soil & Sediment	m	a	t	m	
	Groundwater Potential	m	a	t	m	
	Specific area of landuse potential	m	a	t/n	m	
	Forest	m	a	t	m	
	Residential and Industrial	m	a	t	h/m	
St-Onge, Kugler and Seat, 1975[4] - aspet to a region	**Geoscience Aspect**					1)multi-purposes 2)grouped by subjects of maps 3)non significant of relationship of maps (2 stages?, by expected) 4) low updatable
	Bedrock-lithology structure distribution		c	n	l	
	Configulation of bedrock surface		a	t	l	
	Surficial deposits character, distribution, thickness		c/a	n	l	
	Geotechnical aspects, engineering properties of material, terrain capability		a	n	m	
	Geomorphology, landscape from process		c	n	l	
	Geological hazard landslide, erosion susceptibility		a	n	m	
	Construction material potential bedrock & surficial material		a	n	m	
	Hydrology					
	Physical-chemical of groundwater flow aquifer		a	n	m	
	Potential fluid waste disposal		a	t	m/h	
	Seismic effect bedrock & surficial material		a	t	m	
Gostelow and Browne, 1986[1] Upper Forth Estury, An area of 30 x 25 km.[2] Scotland	**Element maps:**					1)specific purpose on heavy structures planning 2)grouped by degree of inference of maps 3)3 stages of relationship 4)medium to high updatable
	Drift thickness/depth to rockhead	m	a	t	l	
	Contours on the upper surface of glacial deposits	m	a	t	l	
	Drift geology	m	c	n	l	
	Distribution of mine workings	m	d	t	l	
	Derived maps:					
	Engineering geology of solid rocks	m	a	t/n	m	
	Engineering geology classification of soft sediments	m	a	t/n	m	
	Geotechnical cross-section	m	a	-		
	Potential map:					
	Geotechnical planning for heavy structures	m	a	t	h	
Cargo and Mollory, 1977[4]	**Topography**					1)mult-purposes 2)grouped by both of subjects and degree of inference 3)non significant of relationship of maps (2-3stages?, by expected) 4)medium updatable
	Landforms		a	n	l	
	Slopes elevations		a	t	l	
	Hazard		a	t	l	
	Area flood of hericane potential		a	t	m	
	Earthquake risk		a	t	m	
	Landslide and unstable slopes		a	n	m	
	Evaluation maps					
	Suitability for agricultural		a	t	h	
	Industrial or housing development		a	t	h	
	Transportation		a	t	h	
	Waste disposal		a	t	h	
	Other usage		a	t	h	
	Engineering geology					
	Construction materials		a	t	m	
	Soils susceptible to frost		a	t	m	
	Folded rocks, fault, joints		a	n	l	
	Strength of material		a	t	m	
	Earth materials					
	Rock type of bedrock distribution		a	t/n	l	
	Soil		c/a	t/n	l	
	Mineral deposits		a/c	t/n	l/m	
	Hydrology					
	Amount and location of water		a	n	l	
	Quality of water		a	t	l	
	Precipitation		a	t	l	
	Process					
	Areas of erosion		a	t	l	
	Areas of deposition		a	t	l	
	Geological formation					
	Ages		a	t	l	
	Distribution and outcrops		a	t	l	

* **The explanation of abbrevation can be used together with table 2.3 (p. 21)**

relationship of map within each of works. Observation can be concluded as follows:

1) A series which has 2 stages of relationship, It also divided into 2 subcharacteristics

1.1) The series which produced 1 maps in basic stages that have mix of low and medium degree of inference themes, then took to evaluated process to be the high degree themes. The works of Luksamee Jeawechasin in table 2.10 present for this character. She group maps into, "Physiography", as the basic data of area study, that are mix of informations in both low and medium to high degree of inference. Most of information are directly collected from the existing data of several departments. All of them were processed to evaluate the, "Growth, potential", of area into 3 themes of development and 1 themes of groundwater potential. This can develop final informations to use in land planning but difficult to update and reverse checking to methodology, accuracy and reasoning in evaluation of data. This case also appeared in example of Ekkapol (1993), Geomorphological Services Ltd. (1988), Radbruch-Hall (1987), Lozinska (1979), Sunya Sarapirom (1982), Surachai (1992), Tanawat Jarupongskul (1995), and Williams (1983).

1.2) The 2 stages of relationship in a series which produced a stage of low degree of inference themes, then use as the basic map and analyzed to moderate degree of inference themes but not advance into high degree of inference themes. The example of Wilson and Smith (1985) grouped the low degree information into "Element map", and grouped the derived

Table 2.10 To illustrate sample of GILM works which are different in relationship of maps within each of works.

Source/location/coverage	GILM Topics & Themes	Sca	Sit	Hab	Deg	Dianosis of a Series of Maps
Luksmee Jeawetchasin,	**Physiography**					1) multi-purposes ?
1992₃	Climate	s	o	t	l	2) grouped by degree of
	Landform	s	a	t	l	inference of maps
Ratchaburi, Thailand	Soil and soil suitability for agriculture	s	a	n	m/h	3) 2 stages of relationship
	Land use and land cover	s	o	t	l	4) low to medium updatable
Province	Geology	s	c	n	l	
	Mineral resource	s	a	t	m	
	Water resource	s	a	t	m	
	Potential geological hazard	s	a	t	m	
	Growth potential					
	Agriculture development potential	s	a	t	h	
	Industial development potential	s	a	t	h	
	Residential and commercial development potential	s	a	t	h	
	Groundwater potential	s	a	t	m	
Wilson and Smith, 1985₁	**Element maps:**					1) multi-purposes
	Topography and drainage	l	e	n	l	2) grouped by degree of
Bridgend South Glamorgan,	Drift and outcrop geology (stratigraphy, lithology)	l	e	n	l	inference of maps
						3) 2 stages of relationship
Small urban area	Bedrock geology and structure	l	e	n	l	4) medium to high updatable
	Rockhead contours/borehole locations	l	e	t/n	l	
	Derived maps:					
	Foundation conditions	l	d	t	m	
	Mineral resource potential					
	(a) Limestone	l	a	t	m	
	(b) Sand and gravel	l	a	t	m	
	Potential for coast erosion	l	a	t	m	
Mckenzies and Utgard,	**Basic Data Map**					1) multi-purposes
1975₄	Depth of bedrock		a	t	l	2) grouped by degree of
	Flood hazard		a	t	l	inference of maps
	Bedrock geology		c	n	l	3) 3 stages of relationship
	Surficial geology		c	n	l	4) medium to high updatable
	Depth to water table		c/a	t	l	
	Ground water quality and quantity		a	t	l	
	Resource Capability Map					
	Sanitary landfill		a	t	m	
	Residential development		a	t	m	
	Park and recreation		a	t	m	
	Liquid waste disposal		a	t	m	
	Ground water supply		a	t	m	
	Surface reservoir		a	t	m	
	Resource Suitability Map					
	Location of potential area		a	t	h	
	Other informations					
Langer and Johnson, 1978₁	Unconsolidated materials	l	a	t	l	1) multi-purposes ?
	Depth to bedrock	l	a	t	l	2) non significant of
Connecticut River Valley,	Slope steepness	l	a	t	l	grouping of maps'topics
Connecticut East Granby,	Areas with seasonal high water-tables	l	a	t	l	3) non significant of
USA	Groundwater potential	l	a	t	m	relationship of maps
	Floodplains	l	a	t	l	(2 stages?, by expected)
Rural township	Inland wetlands and water courses	l	a	t	l	4) low updatable
	Natural land use intensities (suitability for development)	l	a	t	h	

* The explanation of abbrevation can be used together with table 2.3 (p. 21)

information in medium degree such as geotechnical properties, resource potential and deterioration as coastal erosion potential into "Derived map"., Consideration can be discuss that; these work purposed to produce a series of GILM for preparable of only basic informations to get ready for flexible purposes of study area (the maps in high degree of inference are always excessive specification). The works which has this stages of relationship is significant and capabillty. the other sample of this case are from Freeman Fox Ltd. (1987), Rijks (undate), and USGS. (1978)

2) A series of 3 (and more) stages of relationship, the works of 3 stages of information could be usually illustrate the process of evolution of map in series. Their pattern can be viewed as **"structure"** of series. The obvious sample is the idea of Mckenzies and Utgard (1975) (see table 2.10) they systemize the themes of informations into Basic data map which consist of map in low degree of inference, Resource capability map which are technical properties of area, and Resource suitability map that show location of potential area for landuse activities. Observationally, they used the 2 words "capability" and "suitability" to separate information in medium and high degree of inference. The works that systemize structure of series like theses are the works from, Floyd et al. (1982), Gostelow and Brown (1975), McHarg (1969), Marker and McCall (1988), Mckenzies and Utgard (1975), Montgomery (1969), Nickless (1982), Nikorn Mungkung (1992) and Sunya Sarapirom (1992).

3) A series which has not significant relationship of in series. They are the works that no grouping or grouped by

subjects. The works cannot be considered for evolution of informations. So, they does not appear the relationship between particular maps. However, they could be expected the relationship stages by observed difference of degree of inference of each maps in series. The works that has not illustrated relationship of maps are the works from Arnold et al. (1979), Cendrero (1975, 1987), De Beer (1980), Gonzalez (1977), Helley and Lajoie (1979), Langer and Johnson (1978), Matula and Letko (1980), McCall (1985), Ronai (1979), St-Onge et al. (1975), Tinakorn (1994), Zaw Zaw Aye (1989).

2.5.4 Updating of Information

Updating of GILM in each series would be depend mainly on the relationship in a series and also depend on the habit of demonstration in each themes of map topics. Considerably, the series that significant relationship and has been prepared in thematic form would have high potential to updating because they are easy to change or improve mapping units. Besides, they are flexible to synthesis information in higher degree from the lower degree. The examples of the work such as Floyd (1982); Freeman (1987); Geomorphological Service Ltd. (1988); Gostelow and Brown (1986); Marker and McCall (1988); McHarg (1969); Montgomery (1969); Nickless (1982); Nikorn Mungkung (1992); Sunya Sarapirom (1992); US. Geological Survey (1978); Wilson and Smith (1985).

For summary, the diagnosis study of 67 previous works in the field of GILM which were discussed in the past section can be clearly understood for the nature and status of GILM in several features. The terminology and names of each feature

Table 2.11 To illustrate Limitation of GILM maps in both situation, classic and applied geological information in the used in field of land management.

Limitations of classic geoscience information

1. Existing information derivered from several sources that varies in both scale and details of information. This might introduce error and confusion when information is directly transferred.

2. Map illustrates classic geoscience information is a result from compilation of various geological data. Thus causes difficulty is application.

3. The classic geoscience information map is prepared to demonstrate technical information such as lithostratigraphic formation, geological structure, and hydrological units etc. which is limited only to trained geologist to understand

4. Maps are end product synthesized from several data. Updating of map is not easily done even to geologist when new data is available without go to all steps of preparation.

Samples of maps*

Geological Map (1:250,000)

Geohydrological Map (1:500,000)

Soil Map (1:100,000)

Geomorphological Map (1:XXXXXX)

Limitations of applied geoscience information

1. Existing information derivered from several sources that varies in both scale and details of information. This might introduce error and confusion when information is derectly transferred.

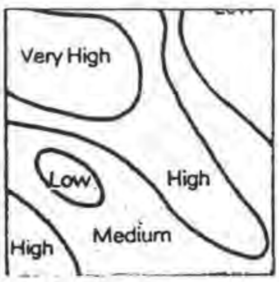
2. Map illustrates several informations together, thus causes inconvenient when some of information needs to be selected

3. Map is prepared to serve specific purposes and can be understood only to certain user, but can be limited to user of different field.

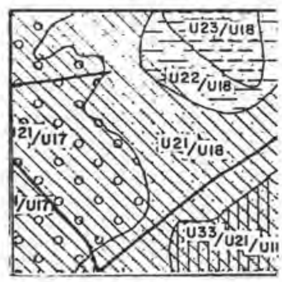
4) Maps are mostly prepared to demonstrate the final result in serving the objectives of application excluding original data. Difficulty occur as mentioned in case of classic map.

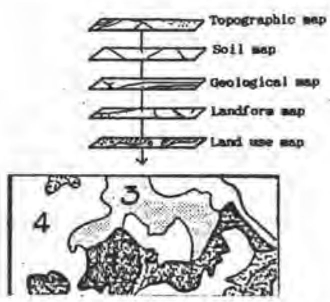
Sample of maps

Hazard Map



Environmental Geology Map





Potential Waste Disposal Site Map

Land Suitability Map

* Scales on the top of each classic maps are the most populalize or standard of map published in Thailand.

were applicable and derived from several sources for used only this research and are not standard or definited for official uses. However, the general knowledges of these are the common senses of informationists, they are no description that be specific and cloudless for GILM, even though for other related fields. So, they cause unclear and misconcept for non professionist to construct GILM. The diagnosis study can be use as basic knowledge to serve purposes of thesis to systemize GILM to practical works. They consist of the systematically view for analysis of problem and limitation of GILM, and systematically view for solution ideas, Both of them are developed to the framework concepts of GILM system.

2.6 Analysis for problem and limitation of GILM

The collection of a number of GILM works and diagnosis of their features could be understood most of characteristics of them. Different of forms or traditions of GILM mapping resulted to some basic problems for the relative practicians, these can be analyzed these problems into 4 involvements.

I) Problems involved with level of detail and level of scale

II) Problems involved with illustration of maps

III) Problems involved with user and map makers.

IV) Problems involved with improvement and updating of informations.

Problem about level of information can be observed from the previous works found that, almost works were directly referred of existing data from several departments. The GILM as geological map, soil map and geohydrological map are the most popularized. Certainly, there are different standards which vary by specific uses of each data source, when more informations becomes misused, the more errors are created in the process of evaluation.

In problem involved with Illustration can be discussed dialectically that most works always have map topics as basic geological map, outcrop geology map , geohydrological map, and geomorphological map in case of the classic maps or environmental geology map, engineering geology map in case of the applied map. The preparation always illustrate for mix of data in several themes in one map, non-thematic habit. This cause use difficult and confuse in extracted only one data themes for specific use of user. So, the structure of information illustrated in the maps are complex and causes difficulty both changing of informations and updating of data when necessary. Furthermore, it has been inconvenient in collecting, processing, and retrieving by computerized scanner and GIS programs.

In aspect of user and map maker, These units mapping are depending on subdisciplines in geology and also the objectives form which the data are prepared. This technical units made it too Šdifficult to understand for general users. In previous works' collection, some of series are not simplified this technical units to non-complex in medium degree of inference, so these are limitation for user who has no sufficient knowledge in that particular field.

In problem about updating of informations, there are only 2-3 previous works that simplified the traditional map into thematic forms.

The systematic summary can be described into 2 situations of informations as following:

1. Limitations of classic geoscience map

The limitations of this situation is from the basic nature of map that are end product compiled from more than one nature of data. The systematically analysis for their problems are as follow;

1.1) Existing information derived from several sources that varies in both scale and details of information. This might introduce error and confusion when information is directly transferred.

1.2) Map illustrates geological information is a result from compilation of various geological data. Thus causes difficulty is application.

1.3) The classic geological information map is prepared to demonstrate technical information such as lithostratigraphic formation, geological structure, hydrological units etc. which is limited only to trained geologist to understand.

1.4) Maps are end product synthesized from several data. Updating of map is not easily done even to geologist when new data is available without go to all steps of preparation.

2. Limitation of the applied geoscience map

The limitations of this situation is from the preparation of maps that usually derive from the number of classic map. The systematic analysis for their problems are as following;

2.1) Existing information derived from several sources that varies in both scale and details of information. This might introduce error and confusion when information is directly transferred.

2.2) Map illustrates several informations together, thus causes inconvenient when some of information needs to be selected.

2.3) Map is prepared to serve specific purposes and can be understood only to certain user, but can be limited to user of different fields.

2.4) Maps are mostly prepared to demonstrate the final result to serving the objectives of application excluding original data. There are some difficulties occur as mentioned in 1.4

2.7 Solution Idea and Framework Concepts.

From observation of previous works, the information features are varied according to map makers and objectives.

There are no standard system to be followed. However, there are some of previous works that have interesting features which can be applied for the solution idea, the creditable previous works are illustrate by file collection in table 2.12, Description of each works are as follow;

Hugh B. Montgomery (1969) has published a concise, systematic examination of data gathering and presentation of environmental data for multipurpose of local development planning. This concept focus on the translation of basic data to units that have a meaning for nonscientists. The map, like the data gathered, must be directed toward planning decision. The philosophy is translating informations into 4 stages. They are the series of basic environmental data, maps of Basic data, Interpreted basic data maps and maps used in making specific planning decision. This concept show the idea to transfer the complex information of classic information to more simple for general uses.

Ian McHarg (1969) has proposed the most popularize methods to integrated environmental factors into land use planning by the map overlay technique. The pattern are translation data for efficient and convenient in evaluation for landuse suitability. The information were prepared in 4 stages which are major data maps, Value maps,Suitable area maps, and Composite map.

Cargo and Mollory (1977) suggested the 8 grouping topics of mapping themes need in landuse planning. Idea of Cargo and Mollory are grouped by subjects and used stage of information but there has not present about relationship of these maps.

Table 2.12 To illustrate selected GILM works which have interesting features to make solution ideas for problems and limitaions of GILM uses.

Source/area/ Groups of Topics & Map Topics	Sca	Sit	Hab	Del	Diagnosis of a Series of Maps
Cargo and Mollory, 1977[4]					
Topography ;Landforms, Slopes elevations	-	c	t	l	1)multi-purposes
Hazard; Area flood of hericane potential, Earthquake risk	-	a	t	m	2)group by both of subjects and degree of inference
Evaluation maps; Suitability for agricultural,Industrial or housing development, Transportation, Waste disposal	-	a	t	h	3)non significant of relationship of map
Engineering geology; Construction materials, Fold rocks, fault joint, Soils susceptible to frost, Strength of mat.	-	a/c	t/n	l-m	4)low to medium updatable
Earth materials; Rock type of bedrock distribution, Soil	-	a/c	t	l	
Floyd, et al., 1982[1]					
Element maps; Topography and drainage ,Drift and outcrop geology (stratigraphy,lithology), Bedrock geology, borehole locations, Drift thickness, Opencast workings/landfill site	l	a/c	n/t	l	1)multi-purposes 2)grouped by degree of inference 3) 3 stages of relationship
Derived maps: Subsidence potential, Predicted foundation conditions, Mineral resource potential	l	a	t	m	4) high updatable
Potential maps: Summary of geological constraints	l	a	t/n	m-h	
Gostelow and Browne,Upper Forth Estury, Scotland,1986[1]					
Element maps; Drift thickness/depth to rockhead, Contours on the upper surface of glacial deposits, Drift geology, Distribution of mine workings	m	a/c	t/n	l	1)specific purpose (heavy structure planning) 2)grouped by degree of inference
Derived maps: Engineering geology of solid rocks and soft sediments, Geotechnical cross-section	m	a	t/n	m	3) stages of relationship 4)high-medium updatable
Potential map: Geotechnical planning for heavy structures	m	a	t/n	h	
Marker and McCall, 1988[4]					1)multi-purposes
Basic geological map	-	c	n	l	2)grouped by degree of inference
Applied geological map ; Mineral resource, Stability/safety	-	a	t	m	3) 3 stages of relationship
Environmental geology map	-	a	n	m-h	4) medium updatable
McHarg, 1969[3]**/Staten island, New York**					
Major data; Bedrock Geology ,Surficial Geology ,Hydrology, Soil drainage environment,Existing landuse,Tidal inundation, Physiographic feature, Geologic feature, Slope, Soil Limitations : Foundation, Soil Limitations : water-table, Soil : most-least erosion	-	c/a	n/t	l-m	1)multi-purposes 2)grouped by degree of inference 3) 4 stages of relationship 4) high updatable
Value Map; Marsh quality, Beach quality, Stream quality, Water wildlife value, Geologic feature value, Physiographic feature value, Seismic value, Ecological value	-	a	t	m-h	
Suitable areas maps; Conservation area, Recreation area ,Active & Passive recreation suitability, Urbanization area ,Residential suitability, Commercial industrial suitability	-	a	t	h	
Composite map; Conservation/ Recreation/ Urbanization areas	-	a	n	h	
Mckenzies and Utgard,1975[4]					
Basic Data Map; Depth of bedrock, Flood hazard, Bedrock & Surficial geology, Depth to water table, Groundwater quality and quantity	-	c/a	n/t	l	1)multi-purposes 2)grouped by degree of inference 3) 3 stages of relationship
Resource Capability Map; Sanitary landfill, Residential development, Park and recreation, Liquid waste disposal, Ground water supply, Surface reservoir	-	a	t	m	4) high updatable
Resource Suitability Map; Location of potential area	-	a	t	h	

(cont.)

* The explanation of abbrevation can be used together with table 2.3 (p. 21)

(table 2.12,cont.)

Source/area/ Groups of Topics & Map Topics	Sca	Sit	Hab	DeI	Diagnosis of a Series of Maps
Montgomery, 1969[a]					
Map of basic data: AIR; Airshed map	-	a	t	l	1)multi purpose
WATER; Ground water geologic map and hydrologic atlas, Topography map showing valleys and stream	-	c/a	n	l	2)group by mix. 3) 3 stages of relationship
LAND: SOIL AND TOPOGRAPHY; Soil map, Topographic map, Landform maps, Orthophoto maps.	-	c	n	l	4) high updatable
LAND: ROCK; Geophysical map.	-	c/a	n	l	
LAND: MINERALS; Georesource map	-	a	t/n	l-m	
Interpreted basic data : AIR; Patterns of pollutant.	-	a	t/n	m	
WATER; Water-supplying strata, Groundwater recharge area, Groundwater quality.	-	a	t	m	
LAND: SOIL AND TOPOGRAPHY; Surface water flow, Thickness, Fertility, Engineering quality, Degree of slope, Flood plain	-	a	t	m-l	
LAND: ROCK; Strata engineering quality.	-	a	t	m	
LAND: MINERALS; Mineral quality or quantity distribution, Mineral area, Mine refuse area	-	a	t	m	
Map used in planning: AIR; Zones showing ability of areas to torelate air pollution resulting from new activity.	-	a	t	m-h	
WATER; Water yield per well or acre foot, Cost per 1,000 gallons of water.	-	a	t	m-h	
LAND: SOIL AND TOPOGRAPHY; Agricultural products grown, including productivity per acre and dollar value of land, Size of area required for septic tanks or sewage disposal facilities ,Wastet acceptance capacity and cost per 1,000 gallons, Ground water level and yield, Soils by origin, Soil slide zones.	-	a	t	m-h	
LAND: ROCK; Areas requiring intense rock blasting, Rockfall and landslide zones, Capacity to accept liquid/solid waste.	-	a	t	m-h	
LAND: MINERALS; Cost per acre for reclamation, Subsidence zones, Underground mine fire areas ,Cost per cubic yard or acre for refuse treatment or for quenching or burial of mine fires.	-	a	t	m-h	
SPECIAL SITES; Location of historic, aesthetic and archeological sites	-	a	t	m-h	
Nickless et al., 1982[1]/Glennothes Fife, Seatland, UK					
Element maps ; Borehole sites, Unconsolidate deposits-distribution, lithology, engineering properties, thickness, depth to water-table, Sand and Gravel thickness, Bedrock Geology, Rockhead contours, Shallow undermining, Natural landslip potential, Opencast workings , Resources-Hard rock for aggregate, Brick and tile clay, Mudstone for brickmaking, Limestone, Hydrogeology	m	a/c	t/n	l	1)multi purpose 2)group by degree of inference 3) 3 stages of relationship 4) high updatable
Derived maps ; Unconsolidate storage Potential within 100 m. of the surface, Sand and gravel potential, Foundation conditions, Groundwater resources	m	a	t	m	
Potential maps (5): Development potential, Priority areas for on-site investigation, Mineral resources-near-surface, buried (opencast), buried (pumping, mining)	m	a	t	h-m	

(cont.)

(table 2.12, cont.)

Source/area/ Groups of Topics & Map Topics	Sca	Sit	Hab	Del	Diagnosis of a Series of Maps
Nikorn Mungkung 1992/Chacheongsao					1)multi purposes
Basic maps Geological map,Topographic map, Geomorphological map, Hydrological map, Soil map	s	c	n	l	2)group by degree of inference 3) 4 stages of relationship
Derivative map; Geological resource potential map, Slope map, Hypsometric map, Groundwater potential map, Population density map, Resource location map, Soil permeability map, Landuse map	s	a	t	m-l	4) medium updatable
Thematic map; Land suitability for housing area map, Possibility of floodprone area map, Waste disposal area	s	a	t	h-m	
Final integrated map; Pleliminary recommendation for regional planning map	s	a	n	h	
Sunya Sarapirom, 1992[3]/Intermontain basin of Northern Thailand					1)specific purpose (road corridor) 2) group by degree of inference
Terrain map ; Land cover, Slope, Cut and fill height, Surficial geology,, CBR, Topsoil,thickness, Difficulty of excavation, Levelling height, Drainage classification	s	a/c	t/n	l-m	3)4 stages of relationship 4) medium updatable
Cost surfaces; Cleaning and gubbing, Topsoil removal, Cut and fill, Embankment cost surface, Drainage treatment cost surface	s	a	t	m	
Intergrated Terrain-cost model ; Terrain cost surface for road construction	s	a	t	h-m	
Final; Selected road corridor with least cost of constructio	s	a	t	h	n
US Geological Survey and Department of Housing and Urban development 1971[1]/Sanfranscisco bay area					1)multi purposes
Basic data; Unconsolidated deposits, bedrock, Landslides, Active fault, Topographic map, Slope map, Bay map, Land subsidence,Ground water, Water bodies, Earthquake location, Mineral commodities, Historic flood data, Rainfall (isohyetal map), Evaporation data map, Soil, Vegetation, Landuse, Water quality and suspended sediment	-	c/a	n/t	l	2)group by degree of inference 3) 2 stages of relationship 4) high - medium updatable
Interpretative studies; Landslide susceptibility, Land use implication region of bay mud, Coastal geologic processes, Physical properties of unconsolidated deposits and land use implications , Hillside materials - inferred engineering behaviour and landuse implication ,Flood-prone area and landuse implication, Urban drainage system, Land pollution susceptibility, Seismic response map, Groundwater studies,	-	a	t/n	m	
Valdiya, 1987[4]					
Regional Landuse Management; Transport network ,Zone of exploitation natural resource, Courbanization land, Land for industrial, Area for water resource development, Zone of bigger natural hazard	-	a	t	h-m	1) - 2) - 3) - 4) -
Rural landuse management; Land supporting forest, Land for water shed conservation	-	a	t	h-m	
Urban landuse management; Stability of ground for foundation structure,Freedom from natural hazard,Site of waste disposal	-	a	t	h-m	

The group of topics are topography group, hazard group, evaluation map group, engineering geology group, and earth material group.

US. Geological Surveys and Department of Housing and Urban Development (1971), designed programs for the San Francisco bay region environmental and resource planning study (SFBRS). It is study of physical environment factors, particularly geological hazard and their relation to urban and regional planning. The products of the study are maps and reports divided into 3 series: basic data contributions, the technical series (derived from the data for a technical audience) , and the interpretive report series (a final derivation for non technical audience such as planner and governmental officials)

Mckenzie and Utgard (1972) concluded the preparation of an inventory of geological information to regional planning in the text title "Man and His Physical Environment". These concept were inventory of all informations into 3 stages of presenting such as basic data maps, resource-capability map and resource suitability map.

Marker and McCall (1988) described to names of maps and summary to feature like stages that relate to degree of inference into 3 groups , " In general, the basic map which show the more or less factual data on various mapped themes should be call "element maps". This will contain more details than any map which shows a higher degree of inference base on a combination of several themes which should be called derive maps and potential map". Marker and McCall has referred to the works which have this pattern such the as **Nickless et al. (1982), Floyd (1982), and Gostelow and Browne (1986).**

For the concept on level of treatment of information, **K.S. Valdiya (1987)** proposed to level of treatment into 3 aspect, they are regional landuse management urban landuse management, and rural landuse management.

In Thailand, the interest works is the study of Preliminary Environmental Geological Assessment for Regional Planning in Changwat Chachoengsao, Eastern Thailand. by **Nikorn Mungkung (1992).** This work appears the clear pattern in 4 stages of relationship of informations such as parent map & initial data, derivative maps, thematic maps, and final integrated map. However, the system was not clear in sequence of interpretation of data.

Sunya Sarapirom (1992) studied terrain evaluation for the road corridors in Northern Thailand by use GIS program . This is systematic study of GILM. The works groups data into 4 groups by degree of inference as terrain maps, cost surface maps, Integrated terrain cost-model maps, and final selected road corridors maps. Though, this investigation is clear to grouping in degree of inference but this work are very specific purposes.

Most of selected works (except Cargo & Mollory and K.S. Valdiya)are predominant in systematic of map topics in grouping by degree of inference, to synthesis maps in higher degree from the lowers. These make clear relationship of maps in each series. But all of them are not unquestionable information systems. They are no only one idea that can be covered all involving of problems. Almost of them are only designed for specific project or specific study area. However, the ideas, concepts or patterns are compiled to make solution idea that conform with the problem and limitation which were discussed in the past topics.

From the study and the observation of previous works, especially, from the selected works, the solution idea has been making, they are as following :-

1) GILM should be prepared to information in different level of details according to level of treatment (e.g. regional and local).

The solution idea is corresponding with suggestion of Valdiya (1987) who has listed for examples of activities' interest in difference levels. They are regional level , urban and local levels. So, the information needed for each level must be consequently designed. Moreover they required to adjust for the error of scale by efficient method such as use of remote sensing image interpretation.

2) GILM should covers all themes of geological information needed, and this must be simplified to be the simplest and thematic details of information.

This solution idea mean to consider and identify the number of possible GILM mapping topics in simple forms in stead of preparation for the one of complex map such as geological map, geomorphological map, soil map, or engineering

- environmental geological map. The works of Montgomery and McHarg were compatible, they listed numbers of map topics which practically use in various landuse activities. However, the work of Montgomery was limited in local level and the work of McHarg was not really in geology subject.

3) GILM should be systemized into the stage of information in order to facilitate user of different status.

This solution idea is very important, this can be served the limitation in aspect of users that are non-geologist. The previous works that proposed relative ideas are from Montgomery, McHarg, Mckenzies and Utgard, Nikorn Mungkung and Sunya Sarapirom.

4) GILM should be constructed into stage of information, starting from data in lower stage of information, and develop to theme in upper stage of information after data are evaluate and synthesized. Thus facilitate in updating and in preparation of information for variation of objectives.

The previous works which had grouped of map topics by degree of inference relative with evolution of maps are corresponding. The significant examples are the works of Montgomery, McHarg, McKenzies and Utgard, and Marker and McCall.

The dialectics of problems, limitation and their solution idea are used to be framework concept. All of them are illustrated conclusively in table 2.13. The formulation of GILM will be discussed in the next chapter.

Table 2.13 Framework concept for systemization of geological information for land management (GILM).

Problem	Limitation of classic geologic inf.map	Limitation of appied geologic inf, map	Solution	Ref. Idea
LEVEL OF SCALE	Existing information derivered from several sources that varies in both scale and details of information. This might introduce error and confusion when information is directly transferred.		GILM should be prepared to demonstrate information in different level of details according to level of treatment (regional and local).	Valdiya
ILLUSTRATION	Map illustrates classic geoscience information is a result from compilation of various geological data. Thus causes difficulty is application.	Map illustrates several informations together, thus causes inconvenient when some of information needs to be selected	GILM should cover all map topics of geological information needed, and this must be simplified the illustration to be the simplest and thematic detail.	Montgomery McHarg
USERS AND MAP MARKERS	The classic geoscience information map is prepared to demonstrate technical information such as lithostratigraphic formation, geological structure, and hydrological units etc. which is limited only to trained geologist to understand	Map is prepared to serve specific purposes and can be understood only to certain user, but can be limited to user of different field.	GILM should be systemized into stage of information in order to facilitate user of different status.	Montgomery McHarg Mckenzies. Marker&McC. Nikorn M. Sunya S.
UPDATING	Maps are end product synthesized from several data. Updating of map is not easily done even to geologist when new data is available without go to all steps of preparation.	Maps are mostly prepared to demonstrate the final result to serve the objectives of application excluding original data. There are some difficulties occur as mention in case of classic map	GILM should be designed according stage of information, starting from date in lower stage of information, and develop to theme in higher stage of information. Thus facilitate in updating and in preparation of information for variation of objectives.	Montgomery McHarg Mckenzies. Marker&McC.