CHAPTER 11

PRELIMINARY DESIGN AND COST ESTIMATE

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11.1 DESIGN FLOOD PEAKS, STANDARDS, AND WADI CHARACTERISTICS

Problem of flash floods in wadis is the one of the major problems in planning road network in the Sultanate. This section discusses this problem from hydrological viewpoint.

11.1.1 General

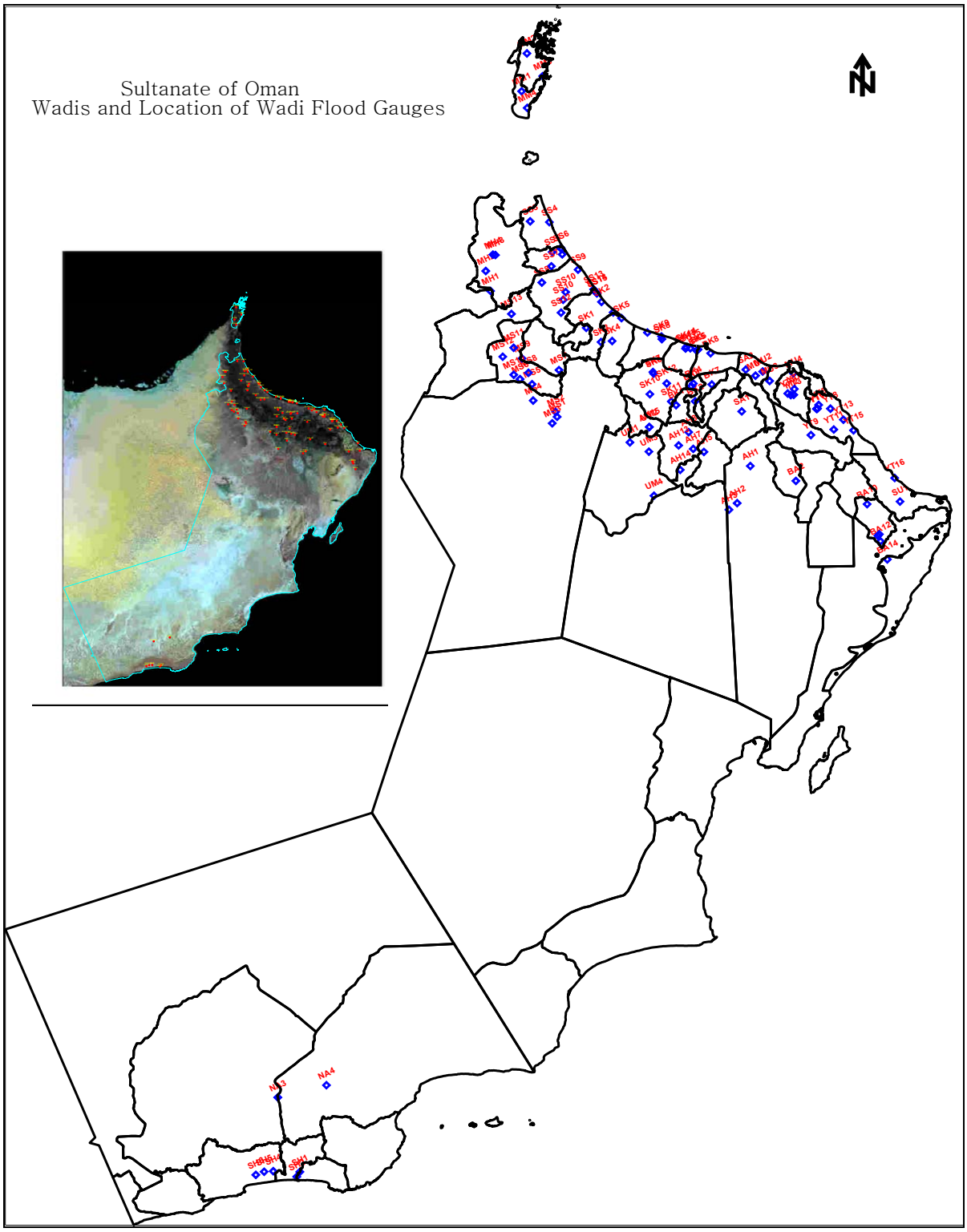
Floods in Oman are hazardous, and difficult to predict: Mean velocities, sometimes in excess of 5 m/s, and high sediment flowage rates are a feature of torrential wadis. Estimates of flood flow with probable various risks of exceedance are indispensable for a wide range of engineering applications including:

- Highway bridge, culvert and dam spillway design.
- Assessment of flood risk, including flood zoning/flood risk mapping.
- Establishment of flood-resistant design and development of flood alleviation, and protection works.

Ministry of Regional Municipalities, Environment & Water Resources (MRMEWR) is responsible for collecting flood data in the Sultanate of Oman, in addition to defining flood features, and providing instructions in specifying national engineering design standards.

The Hydromteorological Monitoring Network embraces 138 wadi gauges 325 rainfall stations; including 216 Autographic recorders is presented in Figure 11.1-1. Channel cross section can be utilized and assessed with the historical information such as flood debris marks from major historic floods, and with the slope, to estimate flood peaks.

The return period of the flood event which the structure is designed to withstand with full factors of safety is commonly taken as the design standard. In some cases (e.g. large dams) there may be two standards, one which the structure should last without any deterioration, and an advanced standard at which repairable damage is allowed, providing the structure remains basically intact.



Note: List of Flood Stations are given in Table 11.1-5 in Subsection 11.1.5

Figure 11.1-1 Wadis and Location of Flood Stations of Oman

(1) Wadi Gauging Stations

One hundred and twenty (120) active gauging stations are currently in operation, and six former stations are now closed. Eight (8) wadi-gauging stations are located downstream of recharge dams which have tangible impact on its flood peak characteristics since their installation. It is noted that the limitation of flood storage in upper gorges means that flood peaks hold up in upper catchment's reaches and flood peaks in the lower catchment's reaches can often be very small proportion of the up stream floods, depending on the relative proportion of alluvial plain.

It is reported that flood characteristics of Dhofar appear to differ appreciably from those in northern Oman. From the maximum recorded flood peaks in Oman, it is observed that nearly all of the highest peaks relate to mountain gorge cases. (Figure 11.1-2)

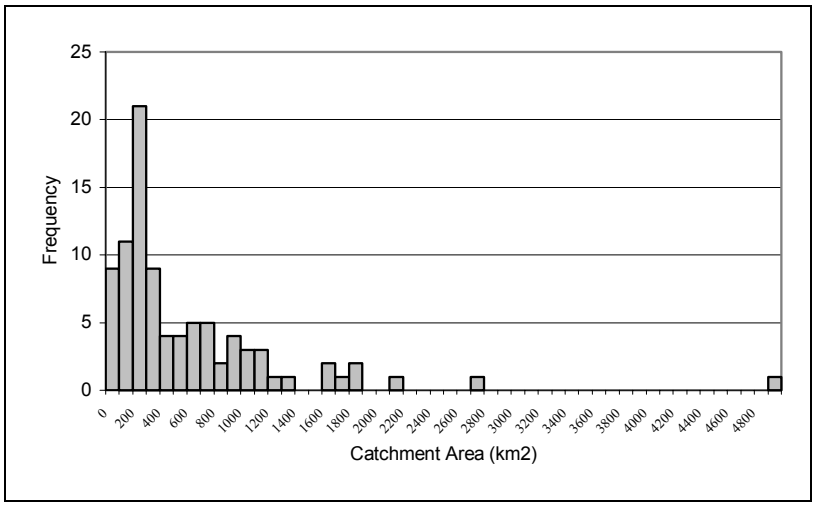


Figure 11.1-2 Oman Regional Flood Frequency Analysis, Flood Data Catchment's Size Distribution

Figure 11.1-3 presents the maximum recorded flood peaks in Oman. These have been selected on the basis of peak related to catchment's area, such that only flood peaks greater than 10% of the world maximum related to area (Rodier, 1984) are depicted, and they are plotted against the world maximum curve. It is noted that nearly all of the highest peaks relate to mountain gorge cases.

The great floods recorded in Oman shown in the figure include the floods of Wadi Dayqah at Mazara in 1927, and 1965, Wadi Ibra in 1927, Wadi Halfayn at Izki in 1951 and Wadi Muaydin at Birkat al Mauz in 1951.

The implication of repeat of the event should be considered in any proposed and prospected development in the vicinity of the ad hoc areas, before any decision on final design parameters are taken.

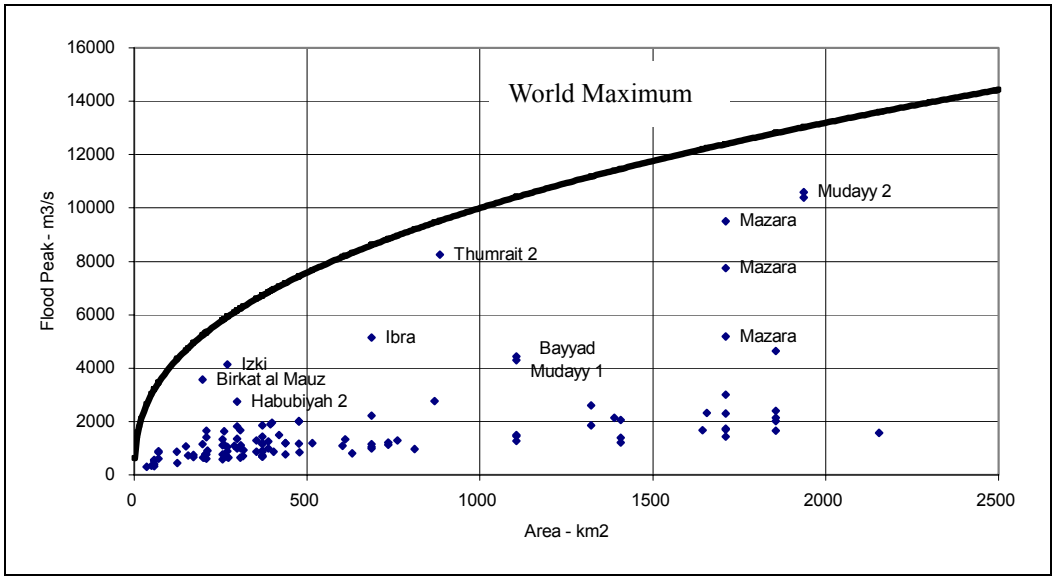


Figure 11.1-3 Greatest Recorded Flood Peaks in Oman Compared with World Maximum (Rodier 1984)

(2) Rainfall

Oman rainfall is caused by five principal weather mechanisms:

- Cold Fronts.
- Tropical Cyclones.
- Monsoonal Currents.
- Convective Storms.
- Orographic Storms.

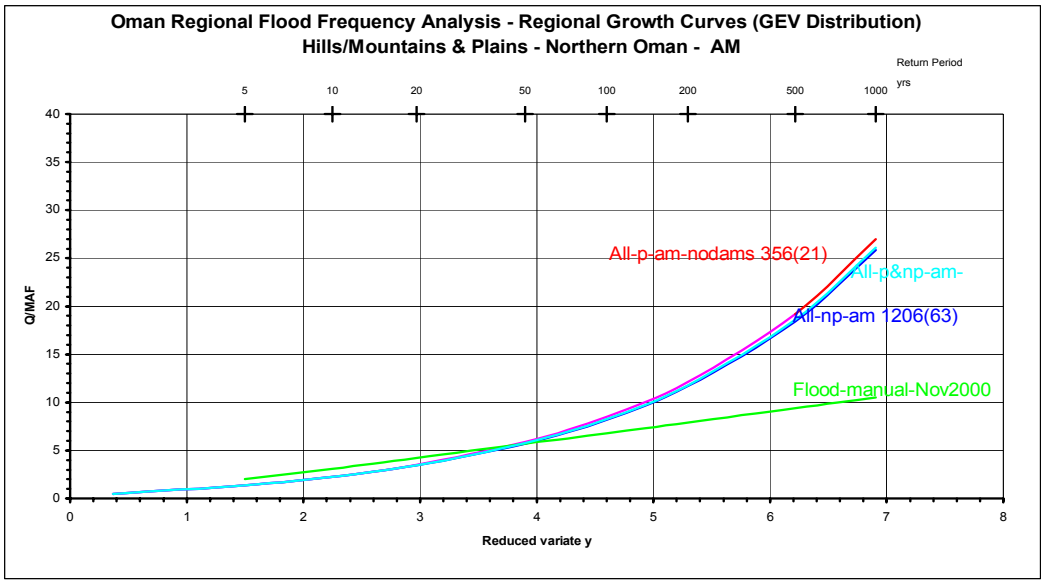
Rainfall intensity, duration, frequency relationship, for use in determining design storm rainfall, was developed by Directorate General of Water Resources Assessment (DGWRA), MRMEWR in 1998. Further, 2000 Master Plan by MRMEWR filled the gap of rainfall data for the period 1975-96 utilizing the data from non-recording rain gauges, of some 2214 station years, from 126 stations including 11 from Dhofar, as well as the data of the study of Wheater, H. S and Bell, N. C, 1983.

11.1.2 Regional Flood Frequency Curves

The methodologies and procedures of the antecedent ways and means for the regional flood frequency analysis have been developed and upgraded by the MRMEWR. The

regional flood frequency analysis for a number of combinations of regional groupings has been utilized in order to identify areas of homogeneity with respect to flood characteristics. The criteria for grouping the stations include administrative region, topography (hill and mountain/plain), catchment's area, and catchment's rainfall. The flood series at each of the selected sites are standardized by dividing each by its relevant mean annual flood. Probability weighted moments are computed for each of the flood series, averaged, and used to derive the parameters of the selected distribution. Dimensionless regional quantities or growth factors are computed for the derived distribution which is used to compute flood frequency curves for each of the sites included in the analysis. An example of regional growth curves of Northern Oman are summarized graphically in Figure 11.1-4.

Compared with the Nov 2000 Flood Manual, the curve for Northern Oman derived in this guide gives lower values, -33% at 5 years and -18% at 20 year return period, then converges at around 47 years and thereafter gives significantly higher values, +22% at 100 years and +50% at 200 year return period.



*p: Plain, np: Non-plain, am: Above Maximum, nodam: Cases where there is no dam in upstream

Figure 11.1-4 Regional Flood Frequency Analysis, Growth Curves for Northern Oman

11.1.3 Mean Annual Flood Estimation Method

The approach to deriving the mean annual flood (MAF) estimation method or MAF prediction equation is to carry out a multiple regression analysis of MAF on the

catchment's characteristics. The mean annual flood is first calculated using the mean of the annual peak flows at the site.

To date, it has been possible to correlate area (A), wadi length (L), wadi slope (S), and catchment's percentage which is non-mountain/hill or alluvial plain (NM). The NM area has been taken as the flat area in the lower catchment, which is indicative of flood plain, recharge and flood routing effects. In the case of L and S, two versions have been tried, one taking the average for the major tributaries, and the second being the more traditional approach of simply using the longest tributary only. Undoubtedly the averaged lengths and slopes provide better estimates of catchment's relative lengths, and slopes.

The rational method is widely used around the world for flood estimation on small rural drainage basins, and particularly for urban drainage design. It is a very approximate deterministic model representing the flood peak that results from a given rainfall, with the *runoff coefficient*. It should be noted that the rational formula approach should not be used for areas greater than about 10 km^2.

The method theoretically assumes:

- That there is no temporary storage of water on the surface of the drainage basin.
- The frequency of occurrence for the peak discharge is the same as the frequency for the rainfall producing event.
- The peak discharge rate corresponding to a given intensity would occur only if the rainfall duration is at least equal to the time of concentration.

The rational method formula is:

$$\mathbf{Q = FCiA}$$

Where,

C = runoff coefficient
i = rainfall intensity in mm/h
A = catchment's area in km^2
F = 0.278 (for SI units)

There are number of formulas for time of concentration including Kirpich and Papadkis & Kazan. The formula adopted for a region should be assessed to ensure that it gives reasonable velocities, and compared with times of rise of observed hydrographs.

11.1.4 Flood Frequency Analysis.

Flood frequency analysis is a tool used in forecasting the frequencies of future floods. Experience has shown that the regional flood frequency curve is more reliable means in predicting flood frequencies, and is to be preferred to estimates made from the data of

single station. There are many catchment's parameters which could be included in the regression analysis, to date, thus, it has been possible to correlate area (A), wadi length (L), wadi slope (S), and percentage of the catchment's which is non- mountain /hill, or alluvial plain (NM).

11.1.5 Development of Currently Used Methodologies and Approach for HDM

The hydrological studies of flood design methodologies are based on the data and studies carried out by the MRMEWR, and on the published Highway Design Manual (HDM) of the Sultanate of Oman.

Three procedures have been adopted, in the process of design flood estimation's methods as follows:

- Standard Frequencies Analysis, where there are suitable nearby flood peak data, available from the records.
- For small catchments (less than 10km^2), the Rational Method.
- For larger catchments (greater than 10km^2), the Mean Annual Floods.

In addition, a new method relying on the preparation of synoptic flood frequency maps for the calibration of above procedures for catchment's areas greater than 10 km^2, and estimating best fit to the calculated values as a practical tool for enhancing the accuracy of results is introduced here. However, those maps have to be handled by professional hydrologists in their estimation.

(1) Standard Frequency Analysis

Flood peak data have been steadily collected for many years, from wadi gauging stations, across the Sultanate. Flood frequencies, from the available stations are computed from flood peaks data. These are continually updated on a regular basis. The method of transposition can be applied to estimate design floods at points of interest.

(2) Rational Method

In the absence of suitable observed data, the Rational Formula approach used in the HDM, is still being used for small catchments. This method uses the time of concentration (T_c) which is the time taken for water to flow from the furthest point of the catchment to the site under study. T_c could be determined using the widely accepted *Kirpich formula*. Recently, rainfall intensity-frequency curves for storm duration up to 12 hours and a means for reducing daily design rainfalls to hourly or shorter have been developed for Oman by Surface Water System Program of MRMEWR. These curves

can be utilized for estimating various storm-durations and average recurrence intervals. The latest results of frequency, rainfall intensities for plains, hills and mountains of the Sultanate of Oman are depicted in Figure 11.1-5.

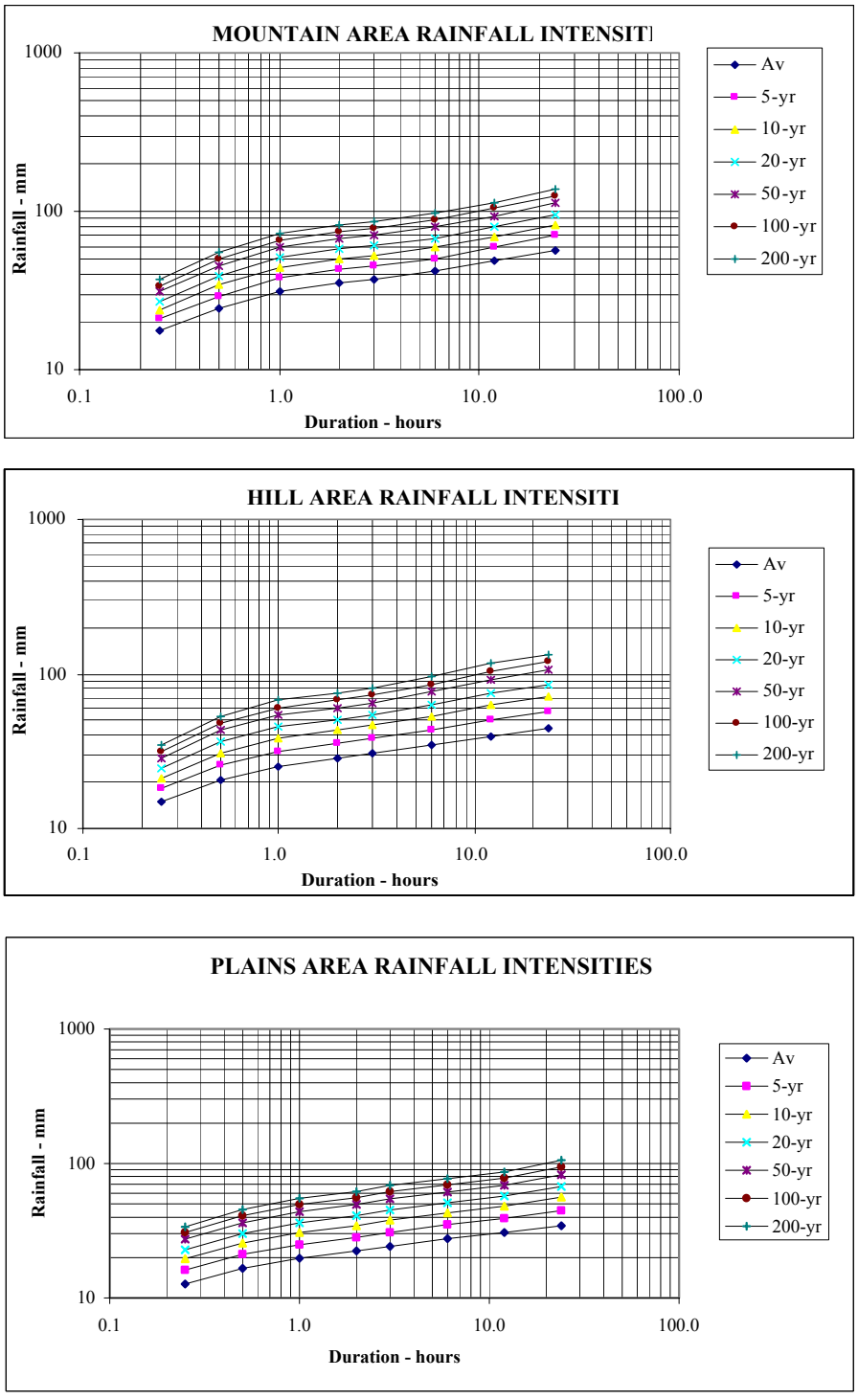


Figure 11.1-5 Frequency of Rainfall Intensities for Plains, Hills and Mountains

(3) Mean Annual Flood Estimation

In order to estimate any un-gauged location of wadi's design flood, a synthetic method has been developed. A station–year dimensionless analysis has been carried out using all available Omani flood peak data for non–overlapping wadi gauging station since many of the lowland wadi gauges, as the case along the Batinah Highway, have multiple channels where the wadi gauges measure only a portion of the total catchment's flow. The method involved the Peak-Over-Threshold flood series (POT) but with mean annual flood using the Annual Maximum series (AM). This is resulted in *flood growth factor*. Deriving mean annual flood is based on catchment's parameters such as catchment's area, slope, length of wadi channel, and degree of alluvium percentage upstream.

Therefore the circular of DGR, No, 68/2000, to all consultants briefly stated the followings:

The flood frequency curves presented in Highway Design Manual, 1994 (Flood Frequency Curves of Oman (FFCO)), were produced based on few years of flood data, and hence, provided crude assumption that catchment's area was overriding catchment's parameter for determining flood peaks. Recent analysis of suitably long records of measured flood peaks has shown that for flatter areas which cover large parts of the nation, and particularly most of the major highways, FFCO tend significantly to overestimate flood frequency leading to costly over design. However, in very steep mountainous areas with gorges, FFCO are more reasonable, but even then they tend to overestimate the long return period floods.

For flood derivation at un-gauged catchments larger than 10 km^2, MRMEWR has recommended the following relationships for:

Hill/mountain catchment's areas

$$\mathbf{Q_{maf} = 2.1 * A^{0.76} * S.15^{0.16} * NM^{-0.142}}$$

Where

Q_{maf} = Mean annual flood

A = Catchment's area (km^2)

NM = Proportion of the catchment which is non hill/mountain (%)

S.15 = Slope of the catchment along its longest tributary, from 15% of its length down from the catchment's boundary to the outlet, in m/km.

Mainly plain /lowland areas

$$Q_{maf} = 1746 * A^{0.883} * NM^{-0.638} * L.15^{-0.553}$$

Where

Q_{maf} = Mean annual flood

A = Catchment's area (km^2)

NM = Proportion of the catchment which is non hill/mountain %

L.15 = 85% of the length of longest wadi extended to the catchment boundary i.e. the length from the point 15% down from the boundary of the inlet, in meters.

The MRMEWR has used the following modified SGWD (Surface and Groundwater Division) Synthetic Method for current calculations

$$Q_{maf} = 1.91 * A^{0.76} * S^{0.2} * NM^{-0.15}$$

The mean annual flood (MAF) value derived using above relationships is to be multiplied by the growth factors of its specific flood growth curves generated recently or its later modification. It is worth noting that above formulas are subject to ongoing modification according to the available and modified data. The overall approach does not differ appreciably from the original formulas.

The following flood growth factors which are subjected to continuous development, have been derived from mountain/hill catchments, and appear to result in somewhat conservative, overestimated, flood frequencies for plain areas.

Table 11.1-1 Flood Growth Factors for Oman

Return period (yrs)	Growth Factor
MAF	1.0
5	1.9
10	2.8
20	3.8
50	5.0
100	5.9

(4) Velocity Estimates

Several models are used in order to estimate flood velocities: HEC-RAS software, SWM, and others available software, are useful programs for the calculation, simulation of watershed flood incidents, and catchment's modelling. Among these, the calculation of flood velocities utilizes topographic data of the cross section, longitudinal section, design discharge flow, and Manning's roughness coefficient (n).

(5) Data collection

The rainfall data can be collected from the MRMEWR, (HDM 1994), and used in the field of the evaluation of minor discharges of the catchment's area. The available 1:100,000 topographic maps of NSA (National Survey Authority), Ministry of Defence, can be used for the catchment's coverage for road alignment.

In order to define water-crossing locations, field inspection program can be organized in order to prepare a specifications list of the existing crossings for further evaluation.

(6) Estimation of flood runoff

a. Design Return Period

For the design of highway structures, culverts, and Irish bridges, return period of flood as, 20, 50 and 100 years can be determined. Table 11.1-2 shows relation of types of structures and frequency of flooding for design of highway elements.

Table 11.1-2 Frequency of Flooding for Design of Highway Elements.

Type of Structure	Frequency
Bridges	1 in 100 years (1%).
Culverts, Irish Crossings, Irish Bridges	1 in 50 years (2%)
Channels and Ditches	1 in 10 years (10%)
Storm Water Systems	1 in 5 years (20%)

b. Runoff Coefficients

The runoff coefficient C for watershed area relevant to topographic features is shown in Table 11.1-3.

Table 11.1-3 Runoff Coefficients

	Average Slope		
Soil and Land Use	Mild (<4%)	Medium (4-10%)	Steep (>10%)
Rocky Intense Cultivation	0.6	0.75	0.85
Loamy Clay Soils	0.5	0.6	0.7
Grass Cover Medium Soils	0.4	0.5	0.6

(After Table 11.2 of HDM)

c. Maximum Allowable Water Velocities

Table 11.1-4 shows maximum allowable velocities for various type embankment materials and pavement/lining prescribed in HDM.

Table 11.1-4 Maximum Allowable Water Velocities

Material	Maximum Allowable Velocity (m/s)
Earth without Vegetation	
Silt	0.2
Fine Sand	0.3
Medium Sand	0.5
Sandy Loam	0.6
Ordinary Firm Loam	0.9
Stiff Clay	1.0 - 1.5
Gravel	1.0
Coarse Gravel/Pebbles	1.5 - 3.0
Soft Shale	1.5 - 1.8
Paved/Lined Structures	
Concrete	5.0 - 7.0
Asphalt	1.5 - 2.5
Grouted Riprap	2.5 - 5.0

(After Table 11.3, HDM)

d. Time of Concentration

Section 11.11 of HDM shows the method to calculate the time of concentration based on Kirpich formula:

$$T_c = 0.0195 * L^{0.77} * S^{0.385}$$

Where;

T_c = Time of concentration in minutes,

L= Catchment main stream length in meter,

S = Main stream slope in m/m

e. Determination of Peak Discharges, (Ref:. Section 11.11 of HDM)

As explained above for natural catchment less than 10 km^2 reference is made to the Rational Method in comparing the calculated discharge, using the Flood Frequency Curves for Oman. The rainfall intensity (I) for particular time intensity used to be obtained from the regional intensity-duration-frequency relationship, shown in Figure 11.2 of HDM. However, rainfall intensity is recommended to be derived using curves of rainfall intensities for plain, hilly and mountainous catchment's areas developed by

MRMEWR, which are attached as Figure 11.1-5 above. The discharge is evaluated using the following Rational Formula:

$$\mathbf{Q = 0.278 * C*I*A}$$

Where,

Q = Discharge in m^3/sec
C = Coefficient of runoff
I = Intensity in mm/hour
A = Catchment's area in km^2

For catchment larger than 10 km^2, the peak discharges are utilized which must be used by the applicants since appreciable modifications and improvements have occurred on the adopted methodologies relevant to the HDM standards of Flood Frequency Curves for areas larger than 10 km^2.

It is worth mentioning that great care should be given to the adjustments of the conventional methods being used until now, which have been subjected to major improvement.

An attempt has been made in order to utilize the calculated Flood Peaks Frequencies for single stations, for different return periods of the main wadi's catchment, to be used as a tool in the calibrated estimation of regional flood peaks in a nearby un-gauged wadi by correlation and extrapolation.

Gridding and Kriking Methods were applied to produce a regularly spaced, rectangular array of flood peak values from irregularly spaced XYZ data. The term "irregularly spaced" means that the points follow no particular pattern over the extent of the map, so there are many "holes" where data are missing. Gridding fills in these holes by extrapolating or interpolating Z values at those locations where no data exists.

A grid is a rectangular region comprised of evenly spaced rows and columns. The intersection of a row and column is called a grid node. Rows contain grid nodes with the same Y coordinate, and columns contain grid nodes with the same X coordinate. Gridding generates a Z value at each grid node by interpolating or extrapolating the data values.

Kriging is a geostatistical gridding method that has proven to be useful and is popular in many fields. This method produces visually appealing maps from irregularly spaced data. *Kriging* attempts to express trends suggested in the data, so that, for example, high points might be connected along a ridge rather than isolated by bull's-eye type contours. *Kriging* is a very flexible gridding method to produce an accurate grid of the data, or *Kriging* can be custom-fit to a data set by specifying the appropriate variogram model.

Kriging can be either an exact or a smoothing interpolator depending on specified parameters. It incorporates anisotropy and underlying trends in an efficient and natural manner. These maps should be used by professional designers for catchment's area more than 10 km^2, as explained in the following section.

(7) Preparation of Flood Peaks Frequency Calibration Maps of Oman.

The above methodology as contained in the said circular, peak discharges have been calculated accordingly. Following the determination of Peak Floods Frequency values in (m^3/sec), based on the updated Flood Peaks Frequency approach for un-gauged catchments, several thematic and synoptic maps for further calibration have been prepared for the first time in Oman, covering northern Oman, Musandam Governorate, and Salalah Plain in the south, in compatible with current developing approach. Ad hoc maps encompassing area distribution of Flood Peaks Frequencies for the calibration of the return periods of 20, 50 and 100 yrs, relevant to the road crossings for the regions under study, were prepared. These maps can be utilised in the calibration of estimated flood peaks discharges, for hydraulic calculations under different Oman's conditions. The following figures show the results of Musandam Governorate, North Oman, and Southern Region (Salalah Plain) calibration maps.

By comparing the above estimated conventional flood peak results with calibrated values, the lower is selected.

In preparing the maps, the data of the gauges listed in Table 11.1-5 were used. The locations of the gauges listed in Table 11.1-5 are shown in Figure 11.1-1. The maps thus prepared are presented in the pages following Table 11.1-5.

Table 11.1-5 Mean Annual Floods of Wadis in the Sultanate of Oman
(Locations of flood stations are shown in Figure 11.1-1.)

Station	Wadi	Station ID	Region	Period of Record	Drainage Area km²	Mean (MAF) m^3/s
Salhad	Al Bih	DD250664AD	Musandam	79-98	222	80
Khasab	Khasab	DD295021AD	Musandam	75-99	299	107
Limah	Nataba	DD368975AD	Musandam	81-99	60	73
Bayah	Khabb Sh	DD245145AD	Musandam	81-98	70	187
Ajib	Hatta	DC237976AD	N Batinah	81-99	437	303
Shinas	Hatta	DC434816AD	N Batinah	83-99	523	105
Sabakh	Fizh	DC417300AD	N Batinah	81-98	266	104
Dawanij	Fizh	DC514700AD	N Batinah	82-99	282	37
Bayda	B Umar Gh	DB496929AD	N Batinah	81-98	275	91
Mulayinah	Al Jizi	DB388507AD	N Batinah	79-98	630	307
Sohar	Al Jizi	DB698772AD	N Batinah	84-97	-	119
Yanbu	Salahi	DM578762AD	N Batinah	83-99	89	58
Riqqah	Hilti	DB576043AD	N Batinah	82-98	242	93
Hayl	Ahin	DB554869AD	N Batinah	82-99	734	405
M Kabirah	Ahin	DB872977AD	N Batinah	83-99	879	59
Khishdah 1	Ahin	DB875654AD	N Batinah	83-97	936	82
Khishdah 2	Ahin	DB875650AD	N Batinah	83-99	-	37
Fujayl	Sarami	DB747538AD	N Batinah	81-98	212	142
Saham	Sarami	DB869846AD	N Batinah	83-98	355	22
Lihban	Bani Umar	DB839224AD	N Batinah	80-98	204	152
Ghuzayn	Hawasinah	DB938385AD	N Batinah	77-98	387	197
Khaburah	Hawasinah	EB057335AD	N Batinah	82-99	878	84
Houqain	B Ghafir	EM304474AD	S Batinah	86-99	591	266
F as Saidi	B Ghafir	EB304504AD	S Batinah	76-99	602	258
Suwayq 1	B Ghafir	EB431349AD	S Batinah	77-99	745	50
Suwayq 2	B Ghafir	EM431747AD	S Batinah	77-97	952	54
Tabaqah	Sahtan	EL381641AD	S Batinah	83-99	165	109
Fara	Fara	EA479986AD	S Batinah	81-99	171	234
Mazahit	Far	EA496507AD	S Batinah	80-98	687	333
Tarif 1	Fara	EM622638AD	S Batinah	84-97	1014	-
Tarif 2	Fara	EM622881AD	S Batinah	83-99	1014	74
Musanaah	Fara	EM626741AD	S Batinah	84-97	-	9
Awabi	Awabi	EL574613AD	S Batinah	85-99	253	121
Ghubrah	Sabt	EA770960AD	S Batinah	82-98	199	121
Hajar	Al Abyadh	EL697332AD	S Batinah	75-98	761	261
Al Abyadh	Al Abyadh	EA698596AD	S Batinah	75-99	767	262
Bu Abali 1	B Kharus	EB722408AD	S Batinah	77-98	1112	36
Bu Abali 2	B Kharus	EM723612AD	S Batinah	83-98	1117	26
Afi	Afi	EL895407AD	S Batinah	85-99	316	231
Hifri	Ma'awil	EM824206AD	S Batinah	83-99	-	36

Station	Wadi	Station ID	Region	Period of Record	Drainage Area km²	Mean (MAF) m^3/s
Dasir	Al 'Uqq	FA160968AD	Muscat	80-98	125	84
Al Khawd	Al Khawd	FB104840AD	Muscat	72-98	1657	285
Seeb	Al Buhayyis	FB211736AD	Muscat	84-97	-	-
Rusayl	Jaba	FB201263AD	Muscat	81-93	114	79
Muaskar	Aiden	FB208640AD	Muscat	79-99	3	11
Hammam	Lansab	FA395799AD	Muscat	80-99	50	57
Bajariyah	Aday	FB505467AD	Muscat	80-99	308	222
Hajir 1	Jannah	FA580672AD	Muscat	82-99	130	31
Hajir 2	Haym	FA583530AD	Muscat	82-98	72	32
Hajir 3	Manzariyah	FA585595AD	Muscat	82-98	210	70
Hajir 4	Mayh	FA596055AD	Muscat	81-99	478	156
Habubiyah 1	Hayfadh	FA777631AD	Muscat	82-99	123	93
Ma'awil	Sarin	FA775288AD	Muscat	82-98	36	34
Habubiyah 2	Sarin	FA776239AD	Muscat	82-95	298	341
Quriyat	Miglas	FA877343AD	Muscat	79-99	554	130
Bayyad	Tayyin	FA740974AD	Muscat	80-99	1105	785
Mazara	Dayqah	FA950420AD	Muscat	75-99	1711	1113
Al Ghaf	Dayqah	FA968370AD	Muscat	76-99	1856	703
Dibab	Arabiyin	GA057335AD	Muscat	81-98	307	278
Qalhat	Hilm	GA413121AD	Sharqiyah	81-99	289	213
Sur	Rafsah	GV497083AD	Sharqiyah	80-99	516	226
Ibra	Ibra	FA507887AD	Sharqiyah	77-99	687	400
Sabt	B Khalid	GV189810AD	Sharqiyah	77-99	370	513
Al Wafi	Didu	GK350499AD	Sharqiyah	88-99	374	56
Bani Bu Ali	Batha	GK336887AD	Sharqiyah	88-99	4991	575
Samad	Samad	FA128240AD	Sharqiyah	81-99	353	194
Sanaw 1	Batha	FV086879AD	Sharqiyah	81-98	731	147
Sanaw 2	Andam	EV989372AD	Sharqiyah	82-99	1407	512
Izki	Halfayn	EA738426AD	Dakhliyah	80-98	270	318
Al Mawz	Muaydin	EA638772AD	Dakhliyah	80-99	197	294
Saiq	Sayh	EA655108AD	Dakhliyah	80-99	7	20
Nizwa	Al Abyadh	EA546034AD	Dakhliyah	77-99	398	259
Adam	Kalbu	EV686593AD	Dakhliyah	82-98	1032	54
Adam 2	Adam	EV539735AD	Dakhliyah	82-98	964	78
Ghafat	Kawr	EA144301AD	Dakhliyah	81-98	260	204
Al Hamra	Misfah	EA350697AD	Dakhliyah	81-99	58	163
Bahla	Bahla	EA330729AD	Dakhliyah	79-99	610	195
Adam 4	Umayri	EV394690AD	Dakhliyah	82-98	2154	203

Station	Wadi	Station ID	Region	Period of Record	Drainage Area km²	Mean (MAF) m^3/s
Sulayf	Lusayl	DA561519AD	Dhahirah	82-98	1807	189
Ibri	Ibri	DA479073AD	Dhahirah	82-98	907	48
Tanam	Al Ayn	DA467001AD	Dhahirah	82-98	2752	131
Subaykhi	Jifrah	DA380054AD	Dhahirah	80-97	452	44
Masharub	Bila	DA299426AD	Dhahirah	82-99	155	102
Dank 1	Bila	DA199915AD	Dhahirah	79-98	233	88
Yanqul	Yanqul	DB502785AD	Dhahirah	80-98	476	310
Dank 2	Dank	DB206512AD	Dhahirah	80-98	1322	436
Khubayb	Khubayb	DB210788AD	Dhahirah	80-98	208	325
Dank 3	Dank	DB103374AD	Dhahirah	80-98	1644	262
Al Fatah	Al Fatah	DB123785AD	Dhahirah	80-98	255	276
Sunaynah	Al Fatah	DB014723AD	Dhahirah	80-98	272	105
Fayyad	Ajran	DB151787AD	Dhahirah	82-97	180	168
Buraymi	Al Ayn	CB973852AD	Dhahirah	82-97	163	68
Mahdah	Mahdah	CB899534AD	Dhahirah	82-98	255	105
Sharm	Sharm	CC907987AD	Dhahirah	83-98	205	191
Nuway	Sharm	CN915047AD	Dhahirah	79-99	208	123
Falls	Darbat	BD298272AD	Salalah	82-98	394	142
Taqah 2	Darbat	BD286800AD	Salalah	82-98	418	117
Mamurah	Rzat	BD095279AD	Salalah	83-99	149	53
Salalah 1	Sahalnawt	AD997284AD	Salalah	84-99	272	49
Salalah 2	Jarziz	AD980966AD	Salalah	83-98	100	12
Mudayy 1	Gharah	YV542060AD	Najd	83-99	1105	232
Mudayy 2	Ghadun	YV751124AD	Najd	83-99	1937	1116
Thumrait 1	Dhahban	BE059867AD	Najd	83-99	1389	137
Thumrait 2	Andur	BE561976AD	Najd	83-99	884	419

a. Musandam Governorate

Figures 11.1-6 to 11.1-8 show changes of Flood Peaks Frequency (FPF), of 20, 50 and 100 years return period, respectively, for areas more than 10 km^2. In case of the return period of 20 years, FPF decreases from 760 m^3/sec around Khabb Sh in the south, to about 420 m^3/sec, around Khasab in the north of Musandam.

In case of 50 years return period, FPF decreases from 1,050 m^3/sec around Khabb Sh in the south to about 600 m^3/sec around Khasab in the north of Musandam.

Likewise, in case of 100 years return period, FPF decreases from 1,200 m^3/sec around Khabb Sh in the south to about 600 m^3/sec around Khasab in the north of Musandam.

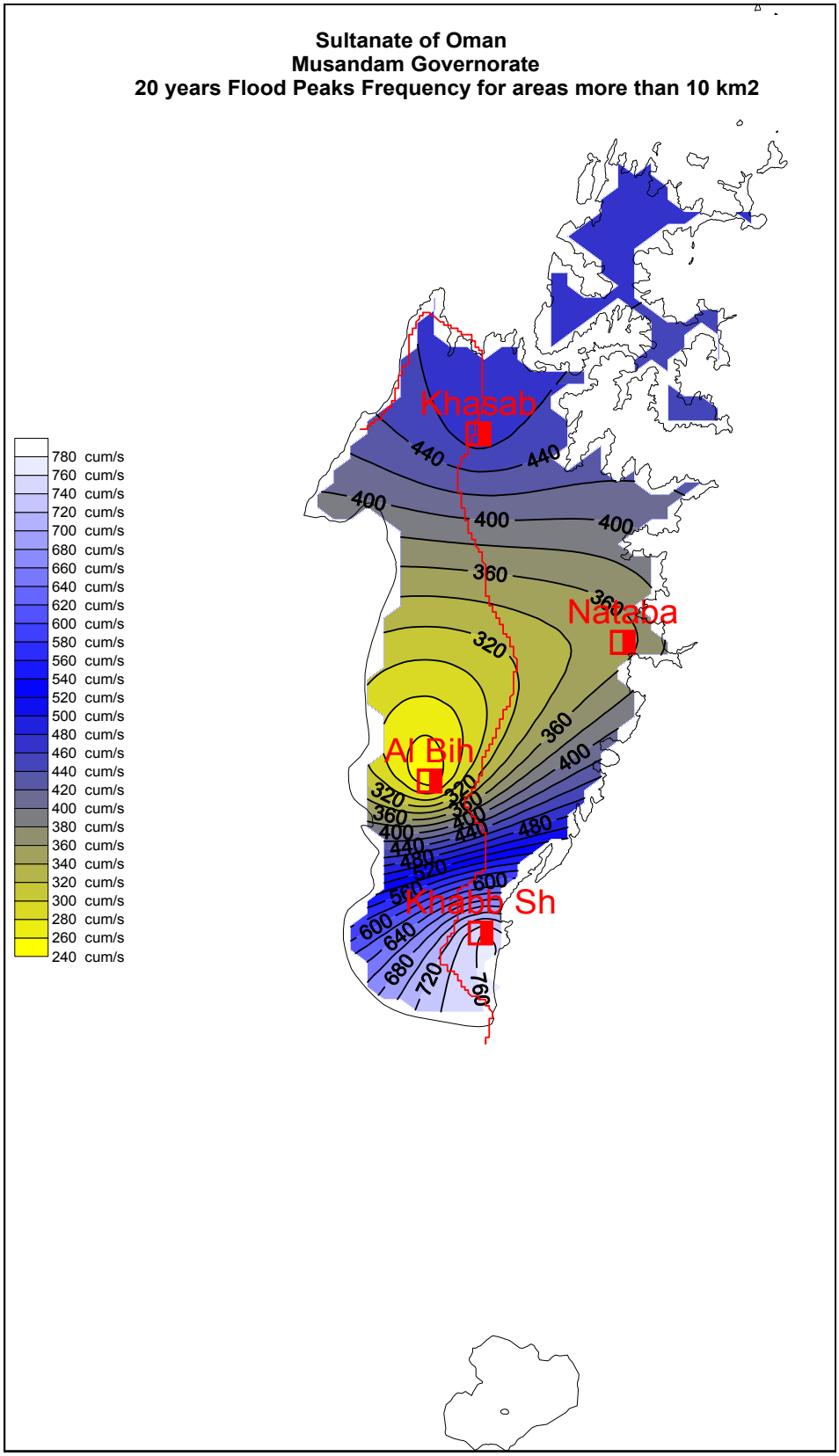


Figure 11.1-6 (20 years) Flood Peaks Frequency of Musandam Governorate for Areas more than 10 km^2

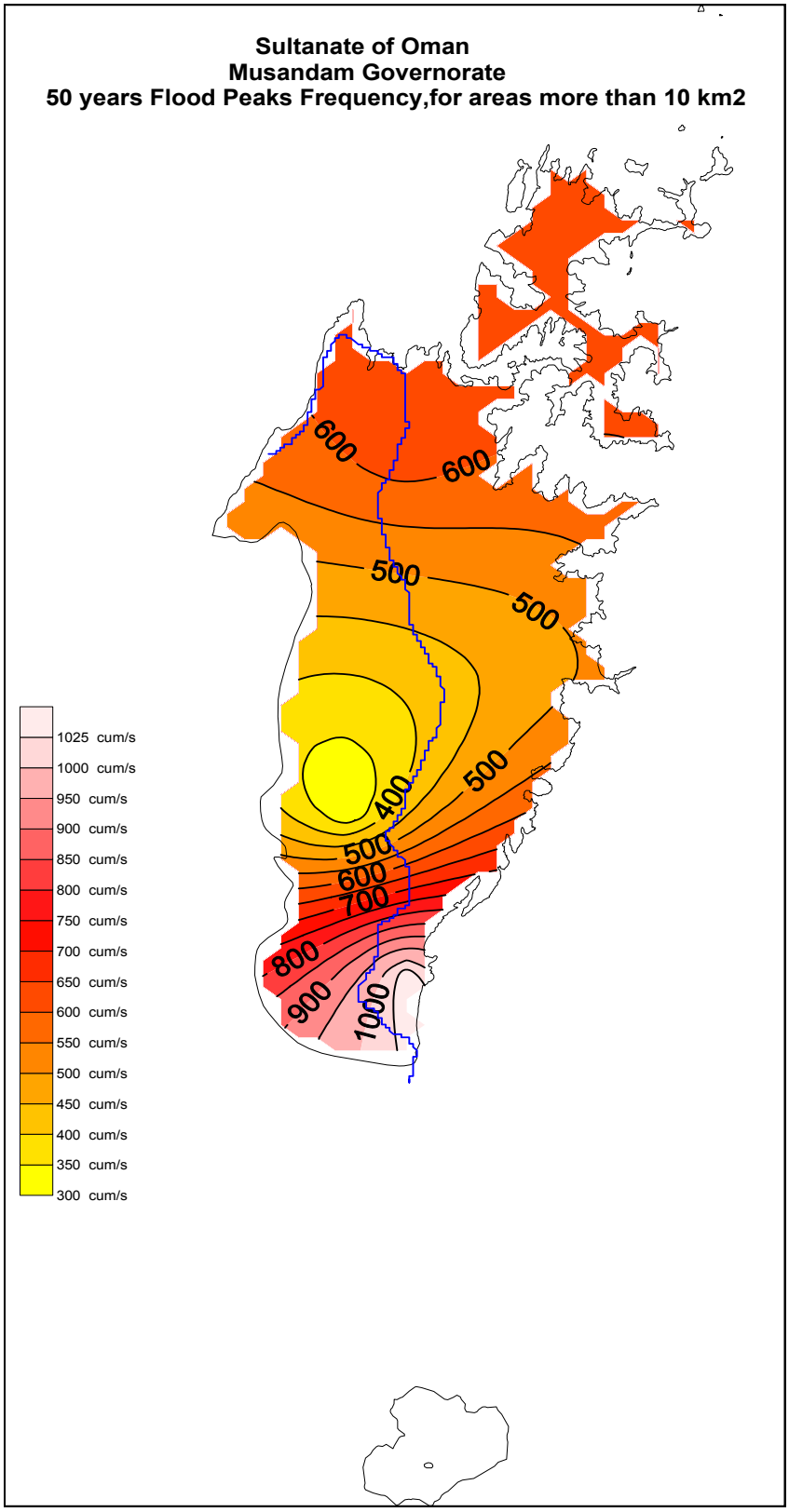


Figure 11.1-7 (50 years) Flood Peaks Frequency of Musandam Governorate for Areas more than 10 km^2

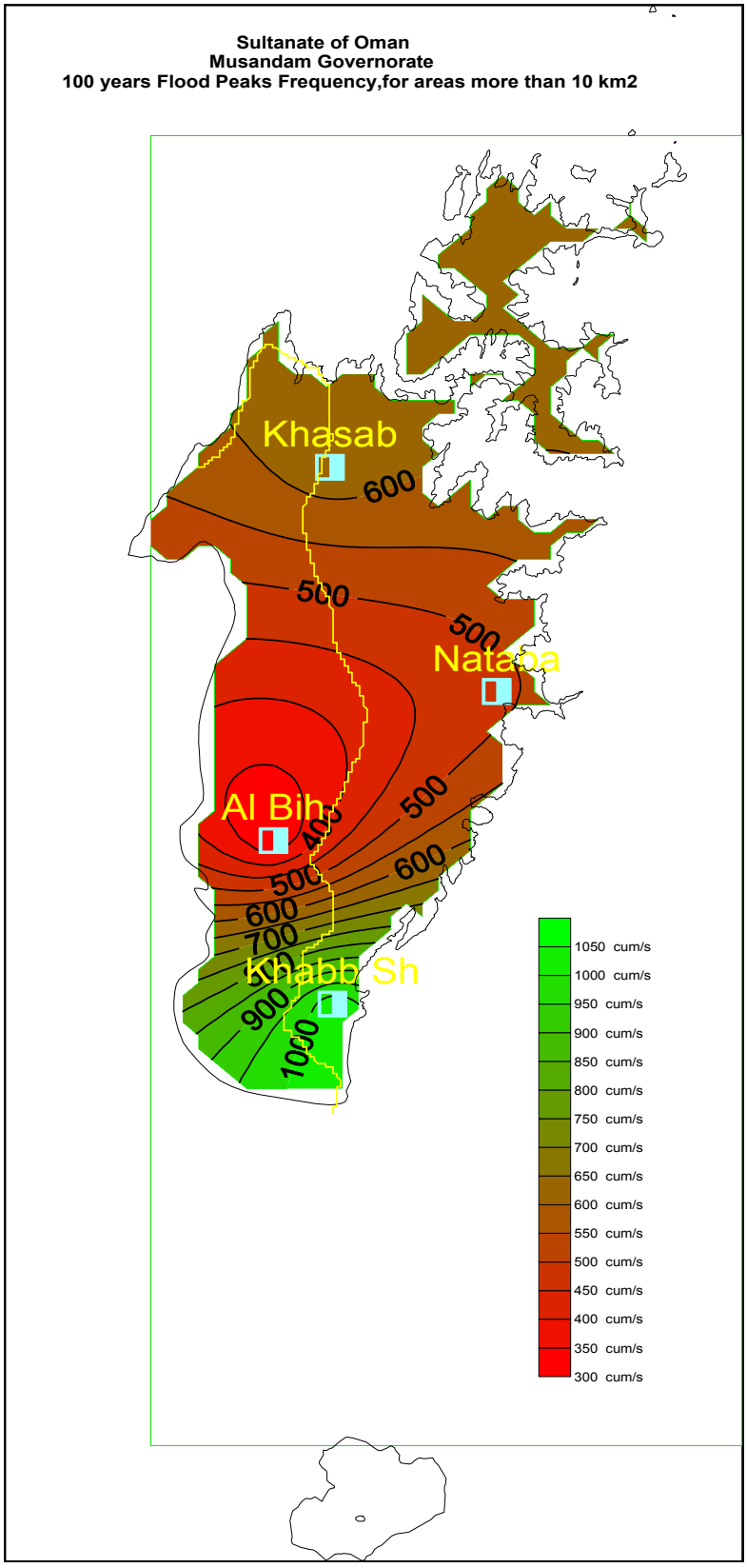


Figure 11.1-8 (100 years) Flood Peaks Frequency of Musandam Governorate for Areas more than 10 km^2

b. Northern Oman

Figures 11.1-9 to 11.1-11 show changes of Flood Peaks Frequency (FPF) of 20, 50 and 100 years return period for areas more than 10 km^2.

In case of 20 years return period, FPF decreases from 3,600 m^3/sec around Al Ashkharah town in the south to about 2,000 m^3/sec around Al Kamil to the north of Al Ashkharah.

The highest recorded flood peaks are seen around Qurayyat and Al Qabil reaching 3,000 m^3/sec, covering NR No. 23 and No. 17, and part of NR No. 15 near Izki. At the north around Dank, FPFs show an area of increased values reaching 1,500 m^3/sec. Values are decreasing steadily towards the coast of Al Batinah.

In case of 50 years return period, FPF decreases from 5200 m^3/sec around Al Ashkharah town in the south to about 2800 m^3/sec around Al Kamil to the north of Al Ashkharah.

The highest recorded FPFs are around Qurayyat and Al Qabil reaching more than 3,000 cubic m^3/sec, also covering NR No. 23 and No. 17, and part of NR No. 15 near Izki. At the north around Dank, FPFs show an area of increased values reaching 2,500 m^3/sec. Values are decreasing steadily towards the coast of Al Batinah.

In case of 100 years return period, FPF decreases from 5,300 m^3/sec around Al Ashkharah town in the south to about 2,900 m^3/sec around Al Kamil to the north of Al Ashkharah.

The highest recorded FPFs are, again, around Qurayyat and Al Qabil reaching more than 3,000 m^3/sec, covering NR No. 23 and No. 17, and part of NR No. 15 near Izki. At the north, also, around Dank Flood peaks show an area of increased values reaching 2,600 m^3/sec. Values are decreasing steadily towards the coast of Al Batinah.

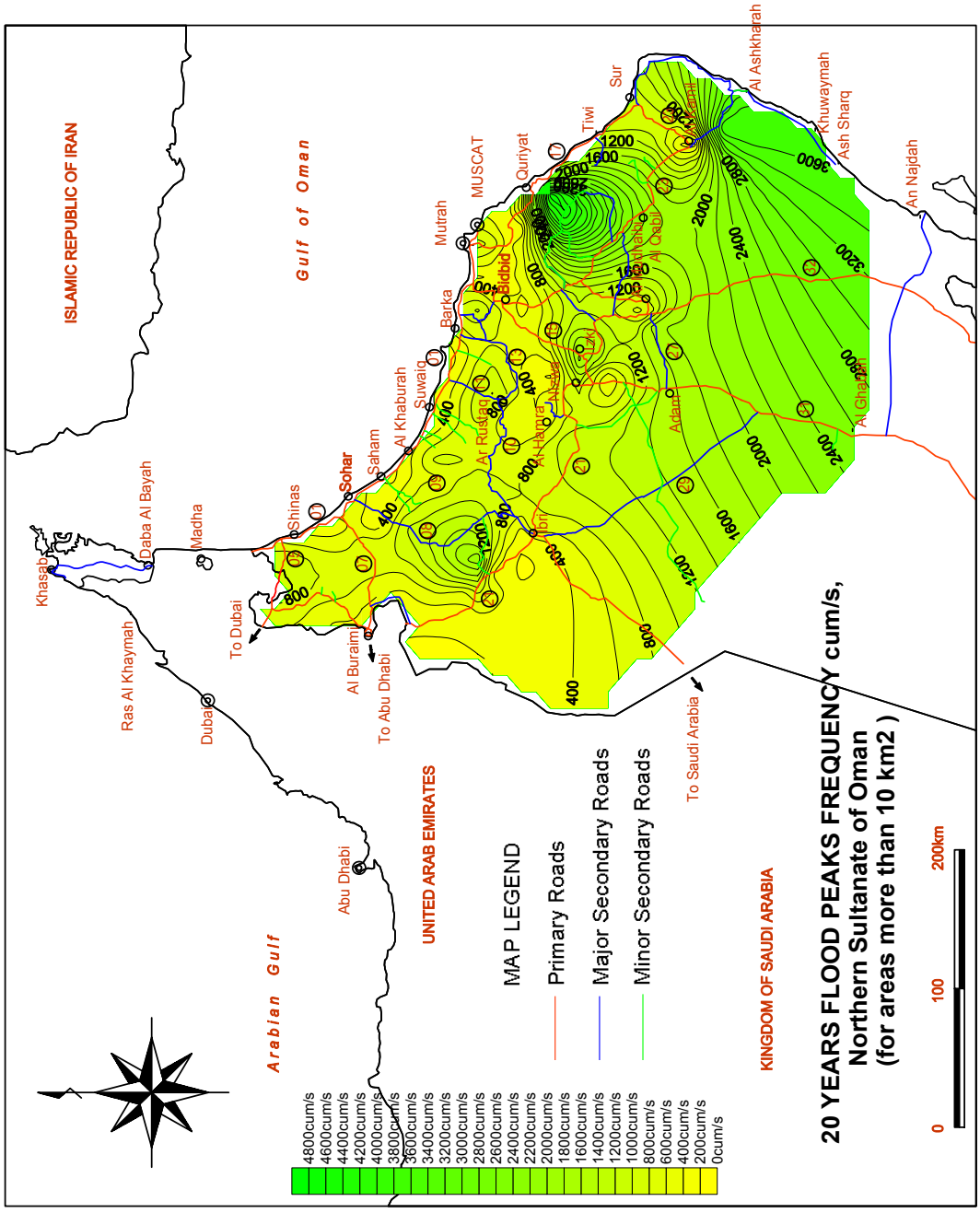


Figure 11.1-9 (20 years) Flood Peaks Frequency of Northern Oman
for Areas more than 10 km^2

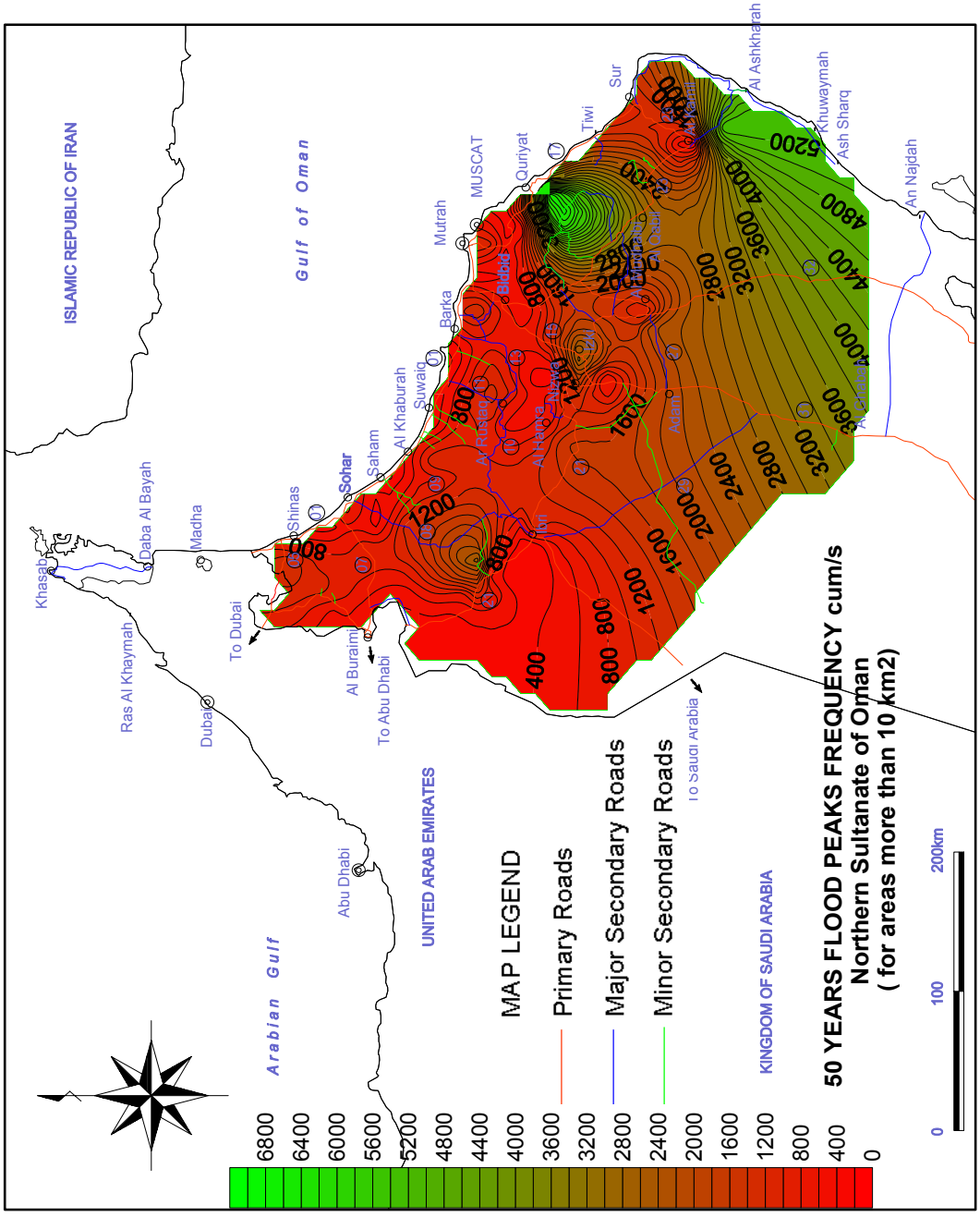


Figure 11.1-10 (50 years) Flood Peaks Frequency of Northern Oman for Areas more than 10 km^2

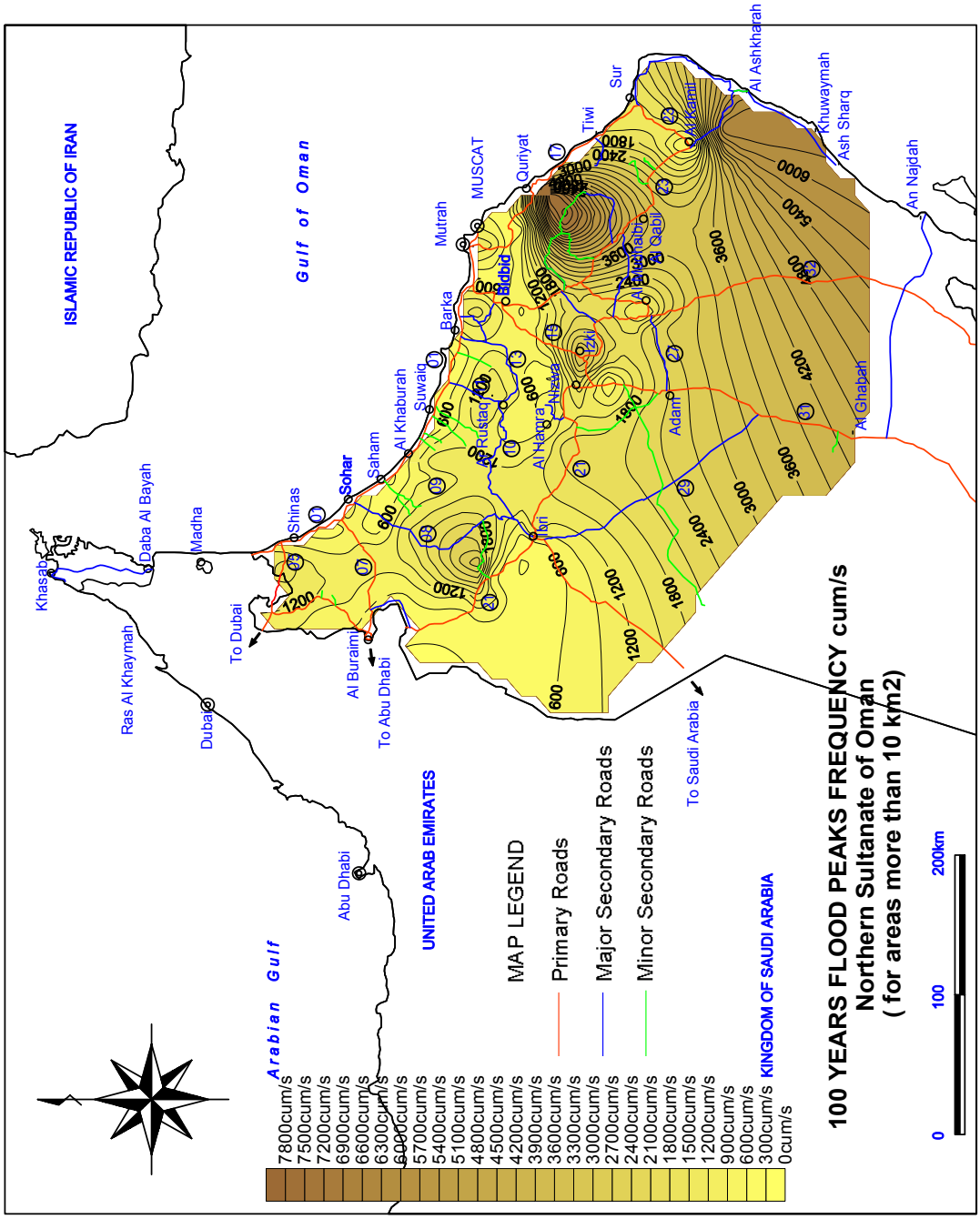


Figure 11.1-11 (100 years) Flood Peaks Frequency of Northern Oman for Areas more than 10 km

Figure 11.1-12 shows the highest recorded flood peaks for 5 years frequency. It should be noted that very high FPFs are seen around Qurayyat and Al Qabil reaching more than 2,000 m^3/sec, covering NR No. 32, No. 23, No. 25, No. 17 and part of NR No. 31 near Ghabah.

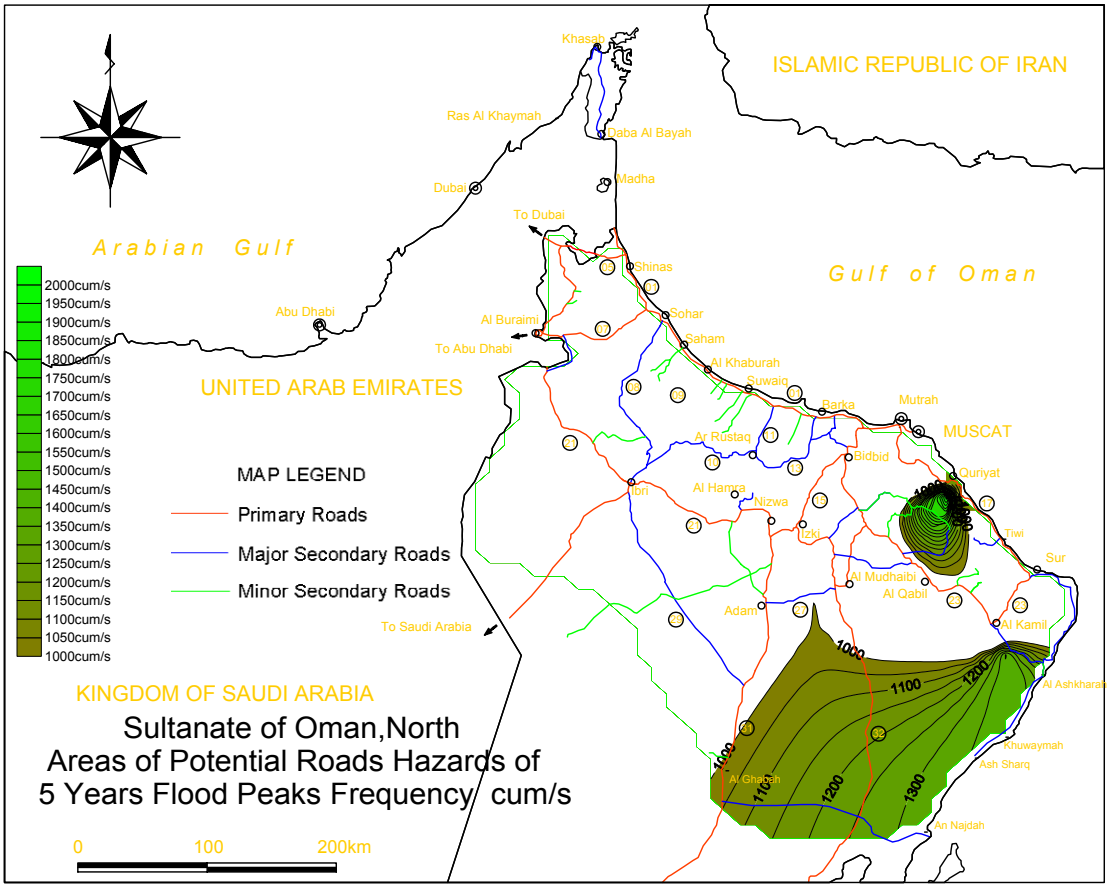


Figure 11.1-12 Areas of Potential Roads Hazards of 5 years Flood Peaks Frequency for Areas more than 10 km^2

c. Southern Region of Salalah Plain

Figure 11.1-13 shows changes of FPF in Salalah Plain of 20 years return period for areas more than 10 km^2. It is seen that FPF increases from 20 m^3/sec around Raysut town in the south to about 400 m^3/sec around Andur to the northeast, covering part of NR No. 39 and No. 31.

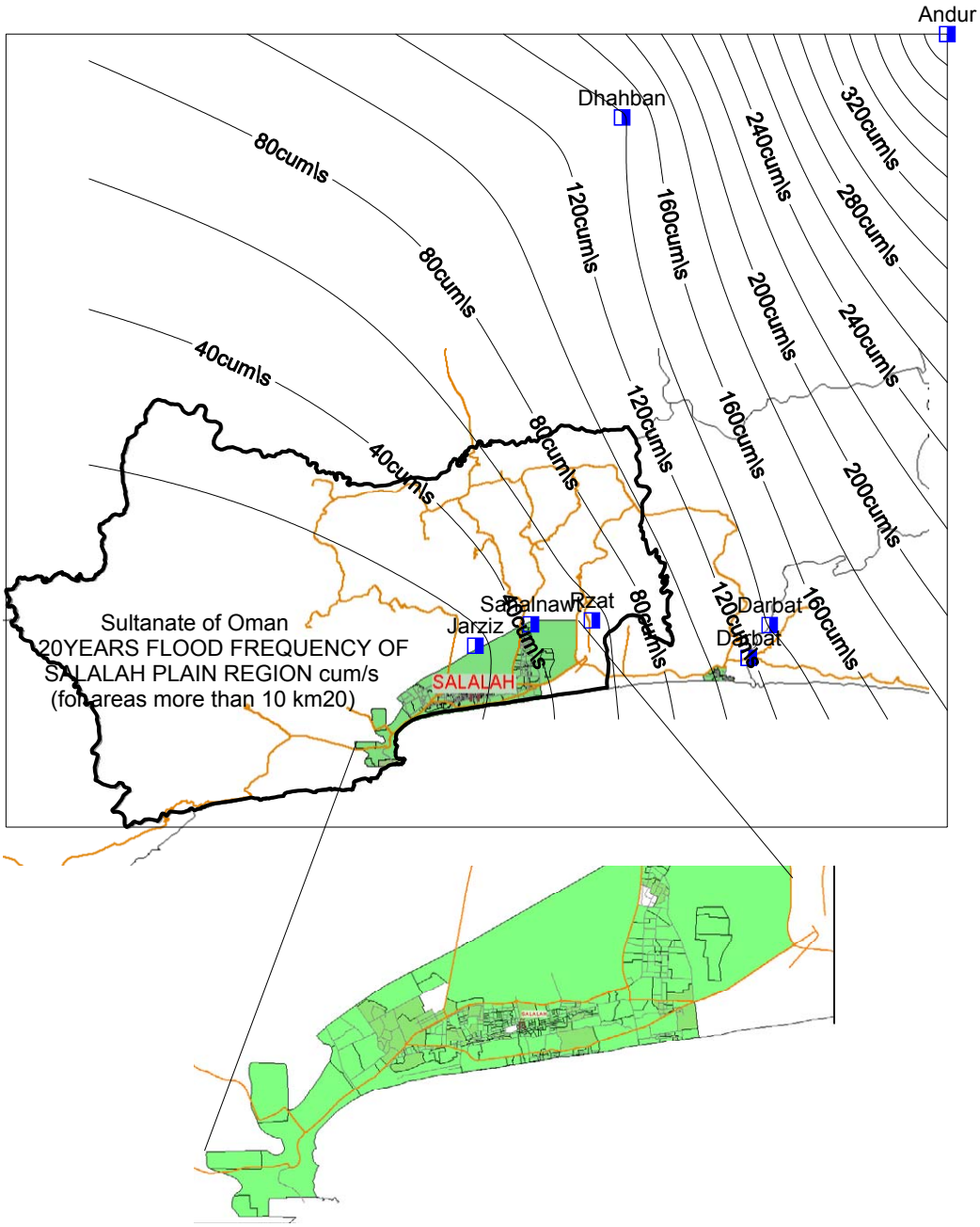


Figure 11.1-13 (20 years) Flood Peaks Frequency of Salalah Plain for Areas more than 10 km^2

Figure 11.1-14 shows changes of FPF of 50 years return period for areas more than 10 km^2. It is seen that FPF increases from 30 m^3/sec around Raysut town in the south to about 450 m^3/sec around Andur to the northeast, covering part of NR No. 39 and No. 31.

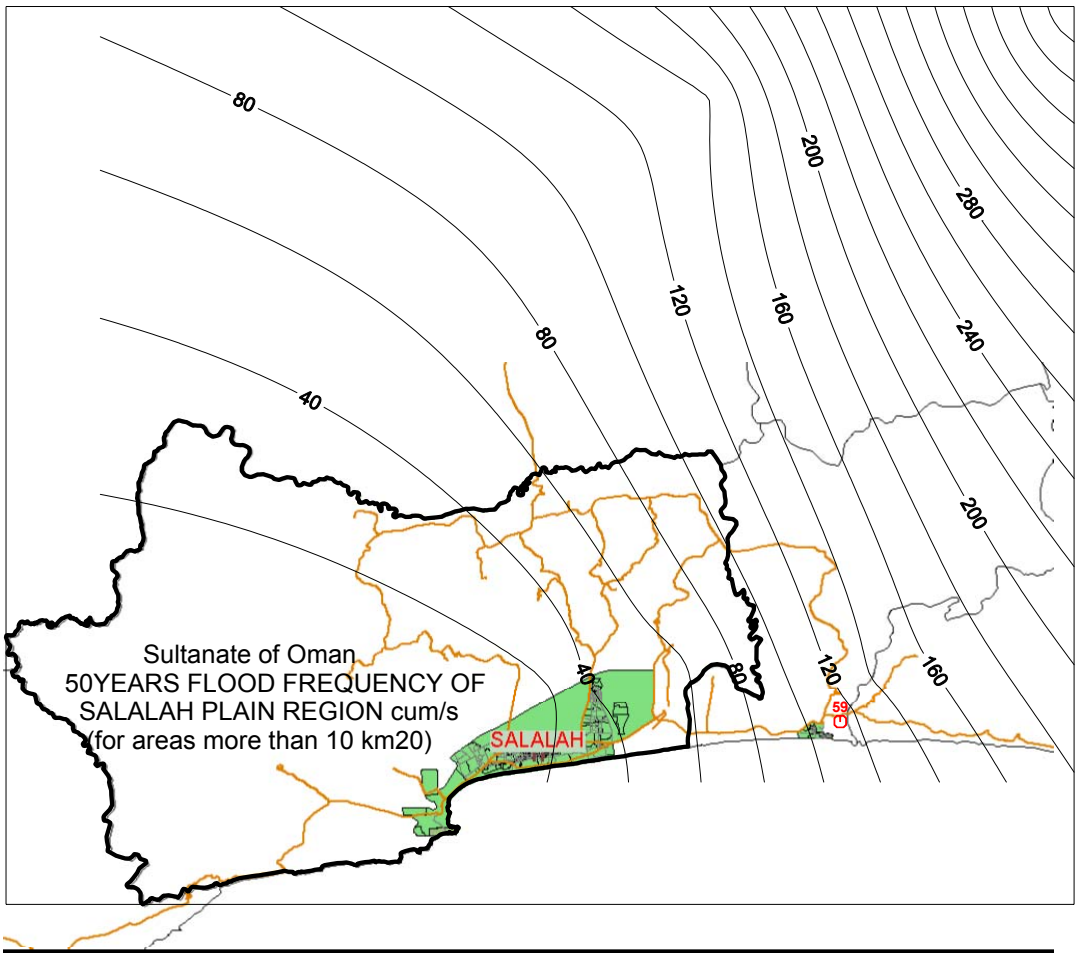


Figure 11.1-14 (50 years) Flood Peaks Frequency of Salalah Plain for Areas more than 10 km^2

Figure 11.1-15 shows changes of FPF of 100 years return period for areas more than 10 km^2. It is seen that FPF increases from 30 m^3/sec around Raysut town in the south to about 470 m^3/sec around Andur to the north east, covering part of NR No. 39 and No. 31.

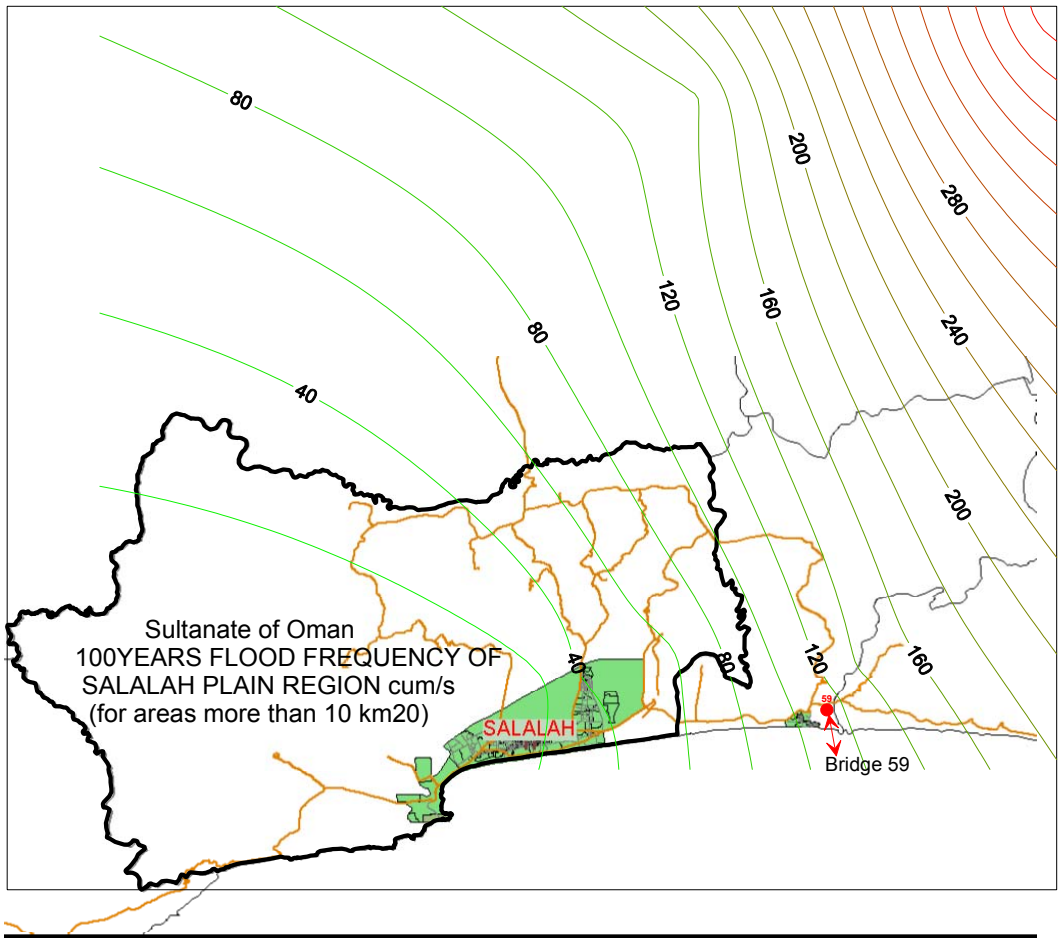


Figure 11.1-15 (100 years) Flood Peaks Frequency of Salalah Plain for areas more than 10 km^2

11.1.6 Oman's Design Standards for Hydraulic Calculations

(1) Open Channel flow analysis

The hydraulic calculations (design) are based on the Omani Standards. Reference is made to Section 11.18 of HDM on open channel calculations for evaluating the flow regime under uniform flow conditions. For cross drainage structures, the following Manning equation (refer Section 11.19 of HDM) is applied:

$$\mathbf{Q= (AR^{2/3}{}_{*}S^{0.5})/n}$$

Where:

Q = Discharge (m^3/s).

N = Manning's roughness coefficient.

A = Cross section of flow area m^2.

R = Hydraulic radius (A/WP)
S = Percentage of slope of channel bed.
V = Average velocity of flow in m/s.
WP = Wetted perimeter (m).

Typical values of Mannig's roughness coefficient, n, recommended by HDM (Section 11.19) are presented in Table 11.1-6.

Table 11.1-6 Typical Values of Manning's Roughness Coefficient, n (HDM)

Concrete lined channel	0.016
Smooth rubble channel	0.020
Reno mattresses or gabions	0.025
Rough riprap	0.040
Gravel, cobbles and not many large boulders	0.030 - 0.500
With large boulders	0.040 - 0. 70

The above formula is used for estimating the capacity of Irish crossing. In this case, R becomes equal to average depth of flow (h) as wetted perimeter is equal to the length of crossing in meters. Generally, for parabolic curves, which are the case for all vertical curves, average depth works out to be 0.65 times the maximum depth.

(2) Irish Bridge, Irish Crossing and Road Protection Discharges:

The hydraulics of Irish Bridge is a combination of "broad crested weir" and culvert discharge. Initially the discharge over the highway is calculated using the broad crested weir formula for a depth of flow 150 mm. The discharge equation is:

1. Broad Crests Weir formula $Q = 1.69W*H^{1.5}$
2. Bernoulli's equation derivation (specific head of flow). $H = V^2/(2*g) + h$
3. Continuity flow equation $Q = W*h*V$

Where

Q = Discharge (m^3/s)
W = Width of the crossing measured along the highway (m).
H = $h+V^2g$: Total energy head

H = Depth of flow (m) above weir and over the highway.
V = Velocity of flow (m/s),
G = Acceleration due to gravity (9.81 m/s^2)

Capacities of Irish crossings can be determined using road weir formula given above, and reproduced below:

$$Q = 1.69\ B\ (H)^{1.5}$$

Where,

B= Length of wadi crossing
H= Specific energy head including average water depth and velocity head.

(3) Discharge through culverts

Nomographs recommended by HDM are used for the analysis of culverts.

Pipe culverts based on Figure 11-7, HDM.
Box culverts Based on Figure 11-8, HDM.

Standard sizes for concrete pipe culvert range from 600 mm to 1,050 mm diameter in increments of 150 mm. Box culverts vary from 1,000 mm to 4,000 mm with a maximum height of 4,000 mm.

An example of some capacity of box/pipe culverts existed in the area can be grouped into various sizes. An example of capacity of one cell of each size is listed below:

PC n (1)	Pipe culverts, n cells of 1.0 m dia	1.6 m^3/s/cell
PC n (.9)	Pipe culverts, n cells of 0.9 m dia	1.2 m^3/s/cell
BC n (1.5*1)	Box culverts, n cells of 1.5 m wide by 1.0 m high	3.0 m^3/s/cell
BC n (2*2)	Box culverts, n cells of 2.0 m wide by 2.0 m high	11.2 m^3/s/cell

The above capacities are based upon Hw/D ratio of 1.2 and are derived from nomographs produced in HDM.

It is worth mentioning, that the difficulties encountered in measuring flood peaks in Oman has resulted in some limitation to the reliability of ad hoc data. Difficulties in measuring flood peaks are such facts as; (i) that wadi flows tend to be swift, and it is dangerous to measure flood peaks, (ii) some wadi gauges are remote and not accessible

during flood incidents, especially when highway Irish crossings inhibit traffic, and (iii) peak flow tends to pass quickly giving no enough time for the surveyor to reach gauging stations, as well as that wadi beds are typically wide and unstable and not ideal for gauging purposes.

11.1.7 Evaluation of Flood Peaks Frequency of the Existing Bridges

Bridges design discharges and coordinates have been worked out using all available data especially on the basis of conventional control methods, calibrated points, and above prepared synoptic calibration maps pertaining to the return periods of 50 and 100 years, in order to be utilized in the evaluation of existing and calculated capacities pertaining to Oman's road network.

The flood peaks frequencies were estimated for the bridges listed in Subsection 4.4.9.

Table 11.1-7 shows the results of flood peaks frequencies determined for the return periods of 50 and 100 years for all bridges.

Table 11.1-7 Calculated Flood Peaks Frequency of Existing Bridges

x	y	Bridge, no	Road no	Flood Peaks Design, 50years Return Period, m^3/s	Flood Peaks Design,100years Return Period, m^3/s	Deteriorated Bridges
225015	1886987	59	6	115	115	
749408	2489715	58	23	1230	1570	
747412	2486222	57	23	1250	1500	
745916	2484226	56	23	1250	1500	
744918	2482231	55	23	1250	1500	
743421	2479736	54	23	1250	1500	
741425	2477740	53	23	1200	1500	
740427	2474746	52	23	1140	1250	
617686	2557572	51	23	1140	1300	
617686	2557572	50	23	1150	1400	
611200	2569546	49	23	590	700	
613196	2573039	48	23	530	650	
477482	2555576	47	21	1240	1500	
531368	2539610	46	21	1230	1500	
555318	2540109	45	15	1400	1500	
587251	2559567	44	15	975	1150	
615690	2590502	43	15	630	780	
616688	2593496	42	15	650	800	
621179	2594993	41	15	600	720	
550827	2581022	40	13	850	1000	d
554320	2579026	39	13	700	900	d
557813	2579026	38	13	675	800	d
564798	2581022	37	13	700	820	d
569787	2584515	36	13	800	900	d
577272	2586012	35	13	750	900	d
385676	2677818	34	7	350	370	
390665	2680812	33	7	425	480	
398649	2681809	32	7	525	620	
401143	2681809	31	7	550	650	
403638	2682308	30	7	600	700	
406133	2683306	29	7	650	750	
410623	2682807	28	7	700	800	
414116	2680812	27	7	725	830	
416112	2680313	26	7	750	850	
418606	2679315	25	7	775	900	
420602	2678317	24	7	800	900	
423596	2678317	23	7	820	950	
426091	2677818	22	7	870	980	
429084	2678816	21	7	880	1000	
430082	2678816	20	7	890	1000	
431579	2679814	19	7	900	1000	
433575	2681809	18	7	890	990	
435072	2683306	17	7	870	970	
437068	2684803	16	7	860	960	
437567	2685302	15	7	850	950	
440560	2687797	14	7	800	920	
442057	2688795	13	7	790	880	
443554	2689793	12	7	770	850	
445051	2690291	11	7	750	800	
446548	2690790	10	7	700	800	
449042	2692786	9	7	600	750	
451537	2694782	8	7	600	700	
451537	2695281	7	7	600	700	
453034	2696778	6	7	550	700	
456526	2699771	5	7	600	700	
406632	2688296	4	7	700	820	
424095	2742681	3	1	1300	1500	d
513905	2648380	2	1	600	700	d
478480	2686799	1	1	630	750	d

11.1.8 Record of Damage on Road Caused by Flash Floods

There is no official record of flash floods on road. However, Maintenance Department of DGR started, in year 2002, to issue written instructions for repairing damages of flash floods to the contractors of maintenance. A total of 28 cases of record of such repair works were obtained, with one case being a record of year 1997. Table 11.1-8 shows the recorded cases of repair of damage caused by flash floods. It is noted that many of these recorded cases of flash flood damage occurred on same days. For example, instructions for the damage of Cases No. 2 to No. 5 were issued on 29 June 2002. Those for Cases No. 7 to No.16 were issued on 19 April 2003. Those for Cases No. 24 to No.26 were issued on 15 March 2004.

Locations of the damages listed in Table 11.1-8 are shown in Figure 11.1-17. Figure 11.1-16 shows the flood which occurred on 16 April 2003 near Ibri.

Figure 11.1-16 Flood Which Occurred Near Ibri on 16 April 2003

Although the issuance of written instruction for repair of flood damage was started recently and the number of recorded cases is still limited, the followings can be concluded from this figure:

(i) Many sections of NR No. 15 (Rusayl-Nizwa Road), including a section near Bid Bid, were damaged by the flood of 19 April 2003 (Nos. 7 to 12). (Note that the actual flood may happened before 19 April because the 19 April is the date when the instructions to repair damage were issued.

(ii) Bid Bid area was damaged again by the flood of 15 March 2004 (Nod. 24 to 26)

(iii) In April 2003, another flood occurred in the south of along NR No. 23 (Bid Bid-Sur Road) near Al Kamil.

(iv) Also, it is suspected the damage of Case 17 (dated 28 April 2003) was caused by the flood of 16 April 2003. Therefore, the weather condition of April 2003

was rather unusual.

(v) In addition to above, flood damages are concentrated in Ibri-Diriz area and Nizwa-Al Hamra area.

(vi) Therefore, four areas are suspected to be prone to flood damage. They are; (a) Bid Bid-Izki (NR No. 15), (b) around Al Kamil, (c) Nizwa-Al Hamra Area, and (d) Ibri-Miskin and vicinity.

(vii) Comparing Figure 11.1-17 with Figure 11.1-10, it is known that four areas identified above approximately coincide with the center of high flood peak frequency contour lines.

(viii) Thus these areas are identified as high flood flash-prone areas.

(ix) Damage due to flash flood occurred at different locations and did not happen twice or more at same location in the past 2 years.

Table 11.1-8 List of Past Cases of Damages on Road due to Flash Floods

No.	Date	Region/ Wilayat	Road Name/ No.	Road Class*	Location	Damage Description
1	14/Nov 1997	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	Near Seror village	- Washout the paved road ,R.W - Riprap Gabion,G.R,S.B
2-1	24/Mar 2002	Al Batinah/ Barka	Branch Road of NR No. 01	A	Al Sawa North, Al Jinaynah etc	- Erosion of shoulder and asphalt surface treatment, 20 m etc
2	29/Jun 2002	A'Dakhliyah/ Samayl	Al Mughbariyah – Al Ayn (NR No.15?)	P		Embankment failures as follows: - Samaal, Al Mahrabi/Al Ain Al Dahali Road, 200m
3	↑	A'Dakhliyah/ Nizwa	Tanuf (NR No. 21?)	L P		- Nizwi, Tanouf Al Dahali Road, 200m
4	↑	A'Dakhliyah/ Hamra	Al Hamra - Biladsayt	S		- Al Hamarah, Al Hamara-Bladsayt Road, 150m
5	↑	A'Dakhliyah/ Bahla	Wadi Qurait	L?		- Bahla, Wadi Qurait Road, 200m
6	26/Aug 2002	A'Dhahirah	Wadi Al Jizi NR No. 07	P	Near Al Wasit?	- 50 m embankment failure
7	19/Apr 2003	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	At 4 km & 12 km from Bid Bid Junc.	- Failure of 1350 cu.m Gabion and 480cu.m riprap protectionand 2000 cu.m embankment.
8	↑	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	At 20 km from Bid Bid Junc.	- Failure of 60 cu.m Gabion and 200 cu.m riprap protection and 200 cu.m embankment

No.	Date	Region/ Wilayat	Road Name/ No.	Road Class*	Location	Damage Description
9	↑	A'Dakhiliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	At 21 km & 22 km from Bid Bid Junc.	-Failure of 300 cu.m Gabion and 300 cu.m riprap protection and 1500 cu.m embankment
10	↑	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	At 23 km from Bid Bid JUnc	- Failure of 500 cu.m Gabion and 175 cu.m riprap
11	↑	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	At 24km & 32 km from Bid Bid Junc.	- Failure of 60 cu.m Gabion and 350 cu.m riprap protection and 200 cu.m embankment
12	↑	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P	At 37 km & 47 km from Bid Bid Junc.	- Failure of 240 cu.m Gabion and 10 cu.m riprap protection and 900cu.m loss of riprap
13	↑	A'Sharqiyah/ wadi el uoq	Rusayl – Nizwa (NR No. 15)	P	At 18 km, 21 km & 22 km from Al Mudaybi Junc.	- Failure of 30 cu.m riprap protection and 460 cu.m embankment 100 cu.m loss of riprap.
14	↑	A'Sharqiyah/ Wadi Bani Khalid	Rusayl – Nizwa (NR No. 15)	P	At 12 km & 16 km & 26 km from Wadi Bani Khalid Junc.	- Failure of 20 cu.m embankment and 15 cu.m loss of riprap
15	↑	A'Sharqiyah/ Sur	Bid Bid - Sur (NR No. 23)	P	At 15+300 km from Sur R/A	- Failure of 80 cu.m riprap
16	↑	A'Sharqiyah/ Sinaw	Haymah – Sinaw (NR No. 27)	S	At Uyun & Barzaman.	- Failure of 6 cu.m riprap
17	28/Apr 2003	A'Dahirah/ Ibri	NR No. 09	P	Al Dariz, Intsctn. with Rd. to Yanql	- Washout (45m L x 4.0m W x 1,5m H) - Riprap protection 7m
18	2/Jul/2003	A'Dakhliyah/ Bid Bid	Rusayl – Nizwa (NR No. 15)	P		- Embankment failure and blockage of 4 box culverts
19	4/Aug 2003	A'Dahirah/ Ibri	Branch of NR No. 09	S or L	Maqniyat	- Failure of 150m protection barriers and 830 m riprap protection
20	21/Se 2003	A'Dakhliyah/ Nizwa	Birkat – Sayq	S/L	Hai al Ain	- Embankment failure
21	↑	A'Dakhliyah/ Bahla			Hai Al Saad	- Embankment failure

No.	Date	Region/ Wilayat	Road Name/ No.	Road Class*	Location	Damage Description
22	27/Sep 2003	A'Dakhliyah/ Nizwa			Al Ayn	- Failure of embankment, 255m
23	↑	A'Dakhliyah/ Bahla	Al Saad – Al Manourah (Branch of NR No. 21)			- Failure of embankment, 200m
24	15/Mar 2004	A'Dakhliyah/ Bid Bid	Bid Bid - Sur NR No. 23	P	Near Junc. with NR No.15	Embankment failure, 1380 m
25	↑		Local Rd near Wali Office	L	Bidbid	Embankment failure, 130m
26	↑		Same as above	L	Bidbid	Embankment failure, 165m
27	17/Jan/ 04	Musandam/ Khasab, Bukha, Madha	NR No. 02?	S	Khasab, Bukha, Madha	- Road surface covered by sand and gravel - wash out of unpaved roads
28	20/Mar 2004	A'Dahirah/ Ibri	Branch of NR No. 09	S or L	Hijayrmat	- 802 m^3 of shoulder and embankment failure

* Road Class P: Primary S: Secondary L: Local A: Access

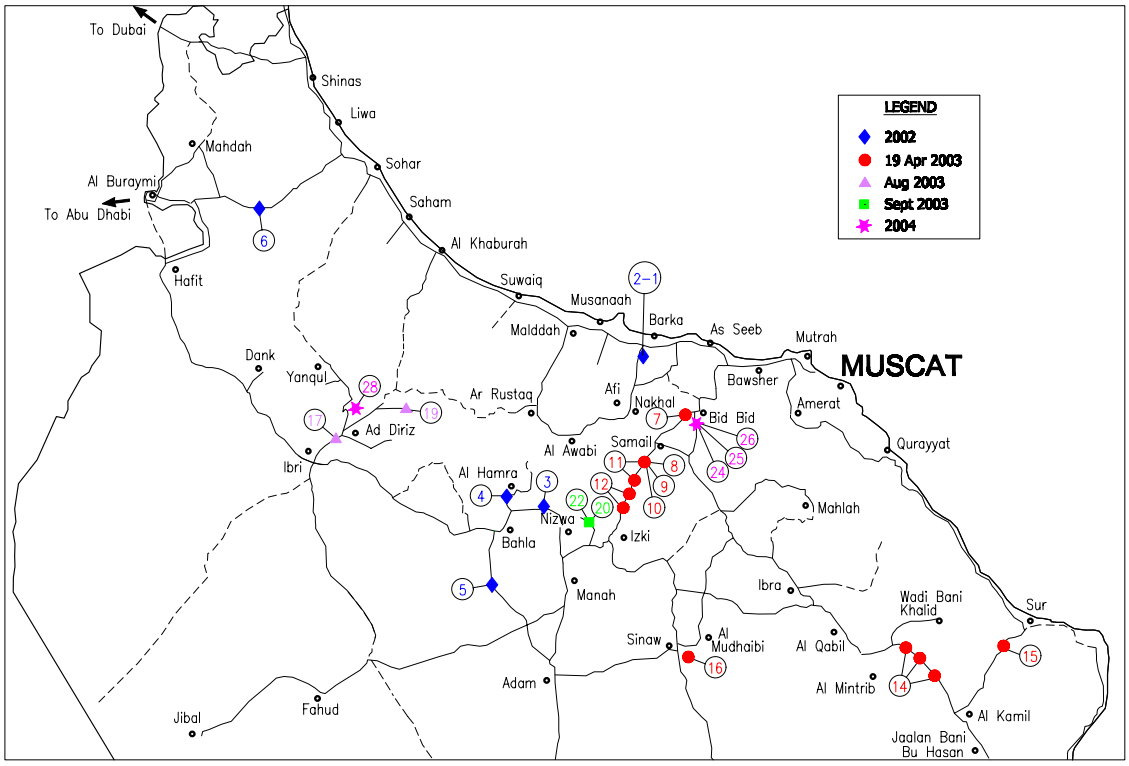


Figure 11.1-17 Locations of Recorded Damages of Flash Floods

11.1.9 Basic Policy for Countermeasures for Flash Floods

One of the difficulties in considering countermeasures for flash flood is that it is very difficult to forecast location and degree of severity of flash flood. In practice, various types of road structure such as bridges, box culverts (Irish bridges), pipe culverts and Irish crossings are adopted to cross wadi. As for protection of embankment slopes, also, various types of slope protection, including mortared riprap and gabions, are adopted based on the judgment of experienced engineers. These measures are considered to be reasonable and are functioning as intended. In addition, road users in the Sultanate are usually accustomed to encounter flash floods and know how to respond, therefore, the problems that flash floods are imposing to the road traffic in the Sultanate are considered to be within acceptable range for many roads.

Further it should be noted that it is impossible to overcome all the natural phenomena. For example, road traffic is stopped by heavy snow, heavy rain and/or strong wind in many countries including those in North America, Europe and Northeastern Asia.

Accordingly, the current practices of wadi measures are fairly reasonable and there is little room left to be improved. This is particularly true with the high number of locations where roads cross or traverse wadis, and limitation over the construction cost.

However, some improvements with reasonable cost and planning/design effort are still possible as follows:

1. For some important road sections which are prone to damage by flood, detour route should be provided to minimize the confusion of traffic.
2. Particularly for Batinah Highway (NR No. 01), conversion of Irish crossing to box culverts should be studied in view of its importance and the large number of pedestrian crossing the highway.

These measures were discussed in Section 8.6.

11.2 PRELIMINARY DESIGN

In this section, engineering standard applied in the preliminary design is described. This engineering standard is also used as a reference for evaluating the construction costs of projects described in Subsection 10.6.3.

11.2.1 Engineering Standard and Specifications

1) General

In 1994, the Sultanate of Oman Highway Design Manual (HDM) was published. The Manual consists of two volumes. Volume 1 supersedes Volume 1 of the Highway Design Standards (1986) issued by the Ministry of Communications. Volume 2 contains standard drawings for use in all road contracts within the Sultanate. It supersedes Volumes 2 and 3 of the Highway Design Standards (1986). On the same year (1994), the General Specification for Roads was also issued. 1994 Highway Design Manual Volumes 1 and 2 are representing the highway standards and 1994 General Specification is presenting the specification for roads.

The Standards laid down in the Highway Design Manual have been drawn up under the guidance of a Technical Committee that includes representatives from:

- Muscat Municipality
- Ministry of Transport and Communications
- Ministry of Defense
- Ministry of Housing
- Royal Oman Police
- Development Council General Secretariat

As mentioned in the introduction of Volume 1, these standards shall be used for all roads schemes in Oman. Where the designer considers that some other standards should be used, the designer must first obtain the approval of the Technical Committee by submitting the proposed modifications through the appropriate channels. Highway Design Manual update No. 1 of Volume-1 was undertaken in year 2000. Update No. 1 of the same volume of year 2003 was the last update. These updates are limited for specified items and do not mean a complete updating of the whole manual.

The major sources of design data relevant to designing roads in Sultanate are:

- GCCS: Gulf Co-operation Council Standards, being produced by the GCC and will be adopted for Oman by the Directorate General for Specifications and Measurements of the Ministry of Commerce and Industry. These will be available in Arabic for many of the main construction materials used in roads. Translation into English will also be available from the Ministry; Arabic is the governing text.
- AASHTO: American Association of State Highway and Transportation Officials. Lay down guidelines for design and construction of highways.
- DOT: UK Department of Transport (formerly known as DT_p). Lay down mandatory requirements for highway design and construction in UK. Also publishes supplementary guidance and background data.
- TRL: Transport Research Laboratory (formerly known as TRRL). Based in the UK it carries out research projects for the DOT and overseas governments.

2) Road Hierarchy

The road hierarchy for Oman has been defined to fit in with the system used in other GCC countries, which can be summarized as follows:

Primary:	Connect larger centers of population and cater for fast moving traffic
Secondary:	Connect smaller centers of population to each other and to primary network
Tertiary:	Provide access to property and connect to the primary and secondary network

Figure 11.2-1 illustrates the application of rural roads hierarchy. The rural road hierarchy and its relationship to the planning hierarchy are set out in Table 11.2-1 based on the updated manual of year 2000.

a. Primary Roads

Primary roads are long distance roads for fast moving of traffic, and form the backbone of road network. Primary roads should bypass towns, but for historic or topographic reasons they sometimes enter towns. Where this happen a primary street (Urban Primary Street) may also serve as a primary road (Rural Primary Road). The main features of primary roads are:

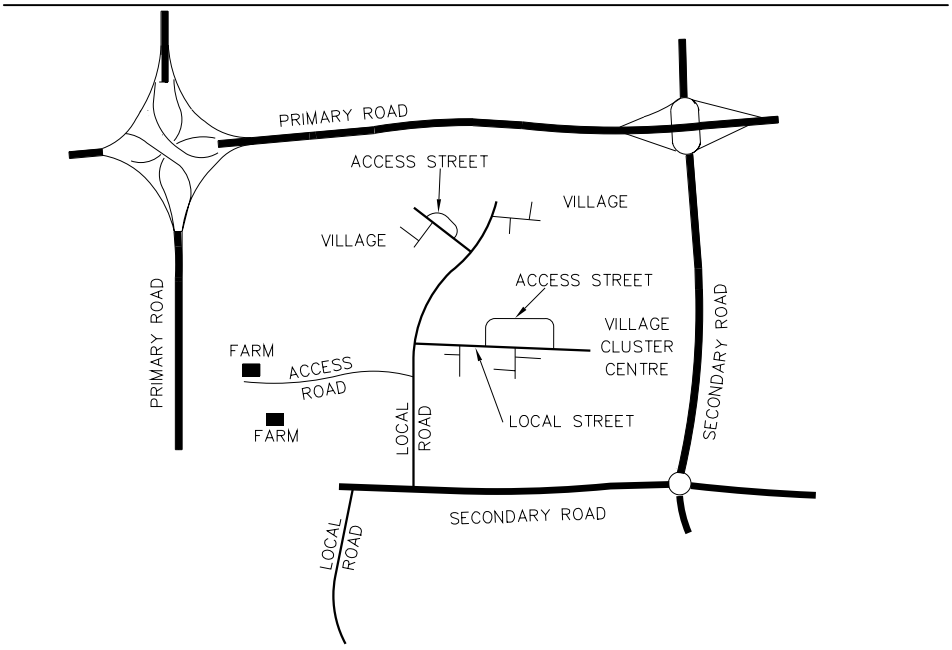


Figure 11.2-1 Illustrative Diagram of Rural Road Hierarchy

- Alignment should be planned to bypass towns and avoid separating communities.
- Where primary road is unavoidably close to residential area, measures should be taken to reduce noise and visual impact.
- Junction will be either at-grade or grade separated as warranted by studies for each case. Where at-grade junctions are used, land should be reserved at major junctions for future upgrading to a grade-separated junction if justified by predictions of future traffic-flows.
- Access to property should generally be from service roads within the right of way or by rear access. Direct access to special land uses, or to isolated individual properties, only permitted where safe with special approval from the Ministry of Transport and Communications, other concern agencies environment as applicable and as well as the Royal Oman Police.
- Pedestrians should be discouraged from crossing the road where visibility is poor. Where significant numbers of pedestrians cross, special facilities should be provided.
- Design speed is 80 ~ 120 km/hr.
- Right of way is 80 ~ 120 m. While most primary roads in Oman will be single carriageway, the wide right of way will allow for construction of a second carriageway if required at a later date. The Supreme Committee for Town Planning has designated those primary roads which have 120 m ROW.

- Spacing between junctions should be at least 3 km on dual carriageway and 1.5 km on single carriageways.
- No parking or stopping.
- Paved shoulder for emergency use only.

The typical cross sections are presented in Figure 11.2-2 based on the update of year 2003.

b. Secondary Roads

Secondary roads provide access from primary roads and connect towns and villages. They should give priority to traffic movement. The planning features include:

- At-grade priority junctions or roundabouts.
- Direct access to property is normally permitted provided traffic volumes are below 200 veh./hr.
- Generally no special provisions for pedestrians are required.
- Design speed 100 km/hr where feasible.
- Right of way is 50 ~ 80 m. ROW 80 m should be used in mountainous terrain where cuts or embankments are required. In flat terrain ROW 50 m is usually sufficient.
- Parking is permitted off the carriageway.

Table 11.2-1 Characteristics of Rural Roads

Attribute	Primary Roads	Secondary Roads
Main Activities	Connect regions	Connect villages and village clusters
Pedestrians	Pedestrian bridges or subways to be provided where significant numbers cross and where traffic is heavy	Minimum activities
Parking	None	Some, but should be off the carriageway
Goods Vehicles	Free movement	Minimal through trips
Other Vehicles, access to the roadside properties	None, except to special land uses or to isolated properties	Permitted only where traffic volume less than 200 vehicles/hr.
Local traffic movements	Very little	Some
Through traffic movement	Main activities (longer distance traffic)	Main activity (medium distance traffic)
Speed limits	Minimum 80 km/hr Preferred for divided (dual) highways 120 km/hr	80 km/hr

The typical cross sections are presented in Figure 11.2-3 based on Update of year 2003. Figure 11.2-4 shows the typical roadway section at sand dunes area.

3) Level of Service and Highway Capacity

Table 11.2-2 shows the design capacity of 2-lane 2-way highways for various running speeds, in different types of terrain and varying percentage of trucks. A 70-80 km/h average running speed should be used for most rural roads in level and rolling terrain. A 60-70 km/h average running speed would be applicable for roads approaching urban areas and wherever feasible for roads in mountainous areas. 50-60 km/h should be used for rural roads in mountainous terrain where higher speeds are not feasible. Table 11.2-3 shows the appropriate level of service for the different area types.

Table 11.2-2 Carriageway Width Versus to AADT

Road Class	20 years after opening AADT	Edge treatment	Access Treatment	Junction options Relating to flow	
				Minor road junction	Major road junction
Normal single carriageway (primary or secondary road).	Up to 13,000.	Minimum 1.2 m paved shoulders.	Restriction of access. Turning movements concentrated. Full paved shoulders at top of the flow range.	Simple junction or single lane dulling.	Single lane dulling or roundabouts
Dual 2 lane all purpose carriageway (primary road)	11,000 to 30,000	Minimum 1.2 m paved shoulders	Restriction of access. Turning movements concentrated. Full paved shoulders at top of the flow range.	Priority junctions. No other gaps in the median.	Generally at grade roundabouts
	30,000 to 46,000	Full paved shoulders	Restriction of access severely enforced and right turns only.	No gaps in the median.	Generally grade separation
Dual 3 lane all purpose carriageway (primary road)	40,000 and above	Full paved shoulders	Restriction of access severely enforced and right turns only.	No gaps in the median.	Generally grade separation
Dual 2 lane expressway (primary road/freeway	28,000 to 54,000	Full paved shoulders	None	None	Grade separation
Dual 3 lane expressway (primary road/freeway	50,000 to 79,000	Full paved shoulders	None	None	Grade separation

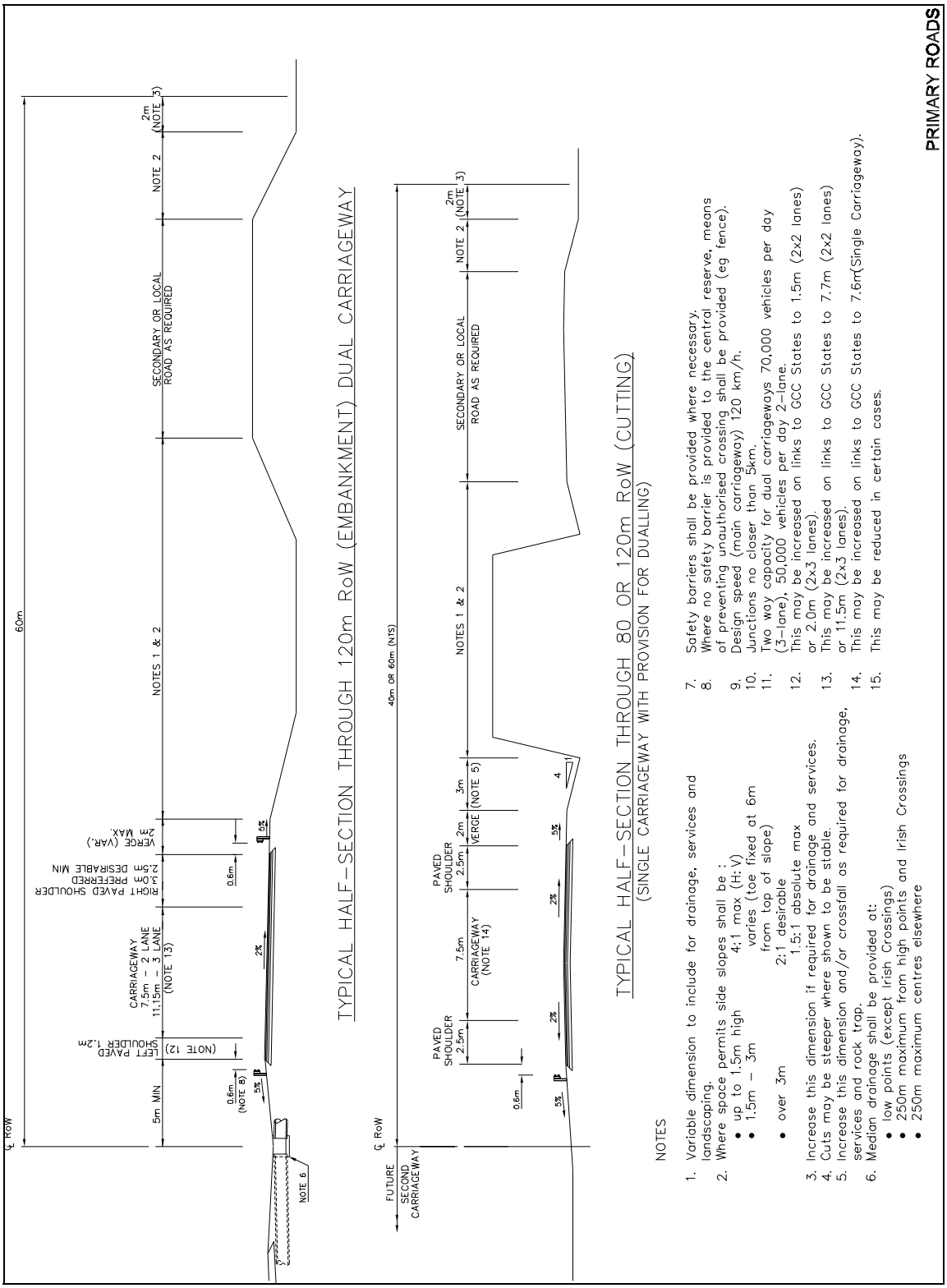


Figure 11.2-2 Typical Cross-Section of Primary Road

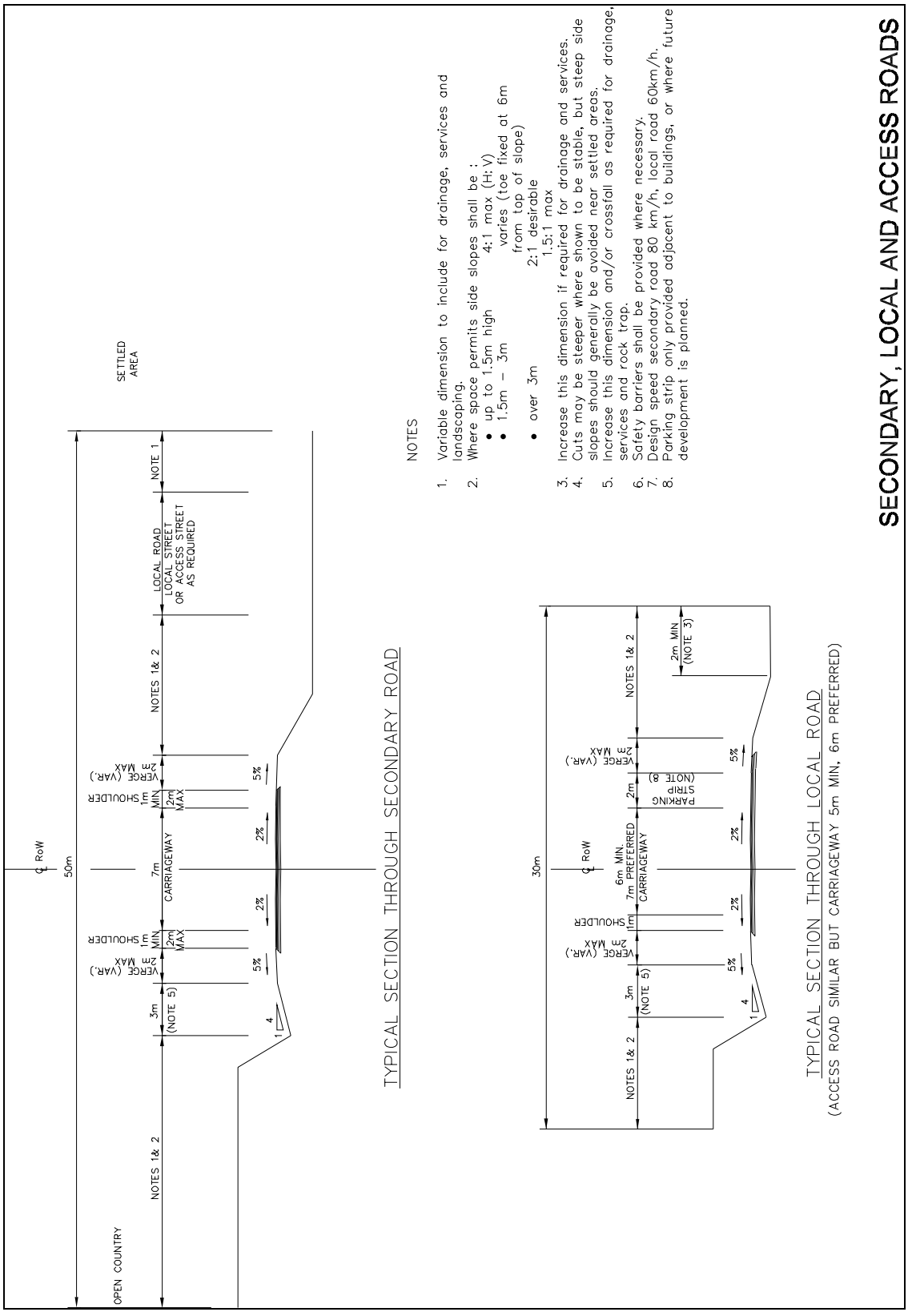


Figure 11.2-3 Typical Cross-Section of Secondary Road

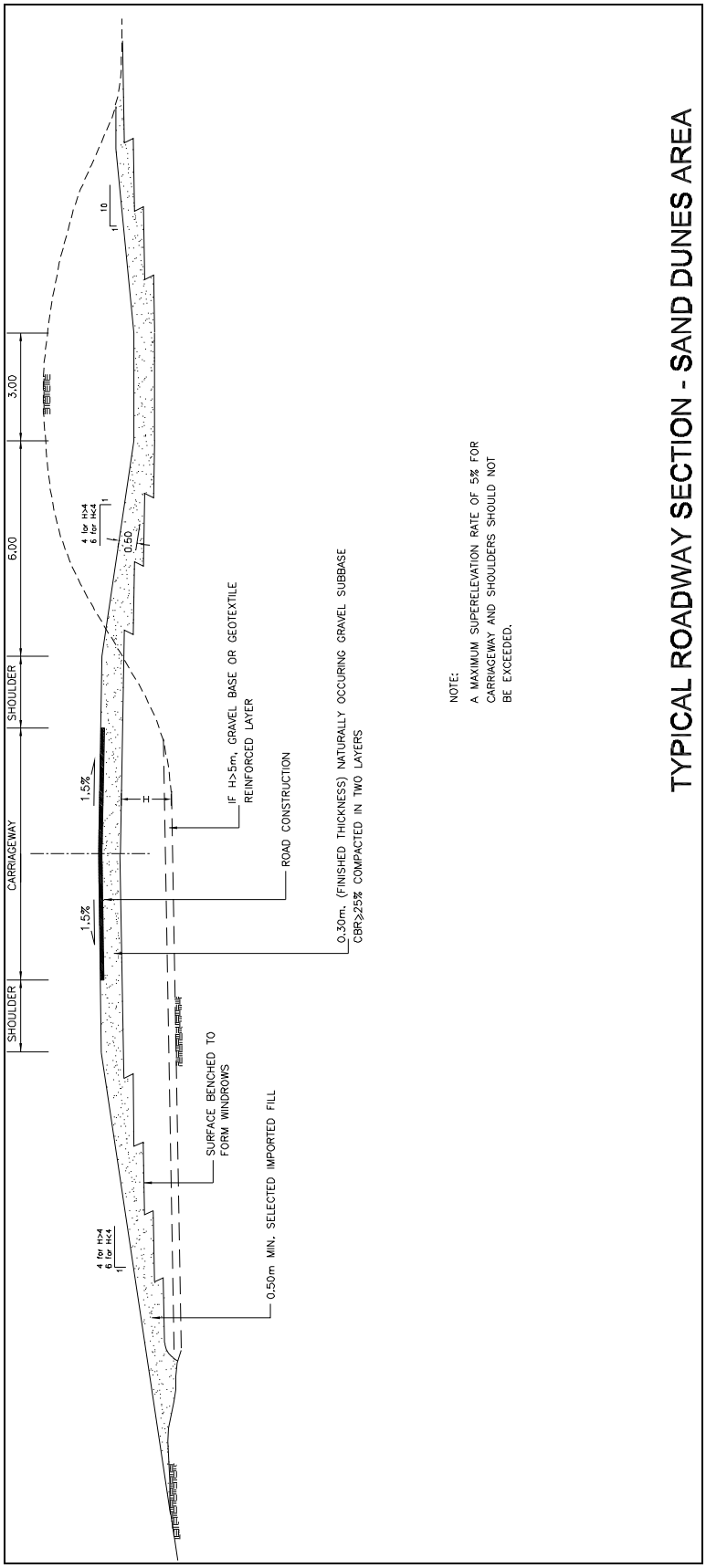


Figure 11.2-4 Typical Cross-Section at Sand Dunes

Table 11.2-3 Level of Service[1] in Design Year

Highway Type	Appropriate Level of Service		
	Rural Level or Rolling	Rural Mountainous	Urban
Primary	B	C	C
Secondary	C	D	D
Tertiary	C	D	D

4) Irish Crossing[2]

Irish crossing can provide an economical and practical alternative to culverts or bridges in appropriate circumstance. They can best be utilized in the following situations:

- Where the drainage path is a wide shallow wadi
- Where the magnitude of discharge along the drainage path is difficult to predict with any accuracy because no rainfall records exist in the area (e.g. interior desert region)
- The horizontal alignment of the road is straight or superelevated on a curved alignment with the cross fall in the same direction as the wadi bed slope
- The daily traffic is relatively low and occasional closure of the road due to flooding would not be of strategic importance

5) Irish Bridges[3]

Irish bridge is more suited to location where the wadi channel is more defined and where it is not economically justified to discharge the peak flow by culverts alone or by bridging.

Irish bridge configuration acts as a restriction to the uninterrupted flow, and consequently creates a backwater upstream of the crossing under medium to full flow conditions. The effect of increased upstream flood level should be considered.

The hydraulics of Irish Bridge design is a combination of:

[1] Level of Service (LOS) D represents the condition where speeds of vehicles begin to decline (due to congestion) and adopted as acceptable lowest LOS in many cases. LOS C represents traffic flow with speeds at or near the free-flow speed.

[2] "Irish Crossing" is the terminology widely used in Oman. It refers the road structure crossing wadi with low embankment, or level with adjacent land which is intended to be overtopped by the stream water during flash flood. Accordingly, such section becomes impassable for vehicles during severe flash flood.

[3] "Irish Bridge" is another type of structure of road crossing wadi. It is continuous, multiple box culverts. The box culverts are designed to let the flash flood water flow through in case of less severe flash flood. However, the total section of culverts is not sufficient to let large volume of water, and, thus the road section becomes impassable during severe flush flood.

i. Broad crested weir and
ii. Culvert design

Initially the charge over the highway is calculated using the broad crested weir formula for a depth of flow of 150 mm. The discharge equation is presented in Appendix 11-1 (page A11-11).

6) Pavement

Pavement shall be designed using AASHTO interim guide for design of pavement structure 1972, revised 1981. As mentioned by the HDM even this reference is updated by 1986 issue but there is currently no experience within the Sultanate of using the soil-modulus test used by the later guide of 1986.

7) Structures

Structures such as bridges, retaining walls, subways, box culverts and gantries, should be designed using AASHTO Standard Specification for Highway Bridges, 13th Edition as modified by the particular requirements for the Sultanate of Oman as summarized hereafter based on HDM.

The bridge carriageway should be corresponding to the road cross-section but in case of bridges having length longer than 50 m, reducing of the bridge cross-section can be considered if the traffic volume on road is quite less than the road capacity and after obtain agreement of the client (DGR). The minimum vertical clearance is 5.5 m and 5.8 m is the desirable clear height. The HDM proposed carriageway widths in case of primary and secondary 2-lane roads are 11.5 m and 9 m, respectively including 4 m and 2 m paved shoulders as bridge approaches for primary and secondary roads, respectively.

Bridges shall be designed for truck and lane loadings as specified in AASHTO but with the following amendments:

- Truck and lane loading shall be HS20-44 increased by 100%. Bridges shall also be checked for special truck type A as shown in Figure 11.2-5.
- The design of bridges on primary roads shall also be checked for special trucks type B as shown also in Figure 11.2-5.
- The maximum impact factor shall be 40%. For special truck type B no impact factor shall be applied.

- A minimum longitudinal force of 450 kN shall be considered.
- Thermal effects should be considered for a maximum shade air temperature of 52° C and for a minimum shade air temperature of 0° C. British Standard Institution BS5400 Steel, Concrete and Composite Bridges should be used to consider thermal and differential temperature effects.
- The acceleration coefficient for seismic loads shall be taken as 0 in Dhofar Region, 0.2g in Musandam, and 0.1g elsewhere.
- The approximate methods for distribution of wheel loads shall not be used. Grillage or finite element analyses shall be used for global distribution; local distribution may use suitable charts.

Box culverts and other structures under roads shall be designed for the same loads as bridges.

11.2.2 Summary of Major Elements of Design Standard

Table 11.2-4 presents a summary of the major minimum/maximum horizontal and vertical alignments standard design criteria based on the HDM.

Table 11.2-4 Summary of Major Standard Design Criteria

Item		Primary Roads	Secondary Roads
Minimum Lane Width (m)		3.65	3.65
Minimum Verge (m)		1.0	1.0
Minimum Median (m)		4.5	3.0
Minimum Shoulder (m)		2.5	1.0
Cross-Slope (%)	Minimum	2	2
	Maximum	4	4
Minimum Vertical Clearance (m)	Light Structures	5.8	5.8
	Heavy Structures	5.5	5.5
Design Speed (km/hr)		120	80
Level of Service	Flat/Rolling Terrain	B	C
	Mountainous Terrain	C	D
Maximum Super Elevation (%)		8	8
Maximum Gradient (%)		6	8
Minimum Radius (m)		50.0	50.0

VEHICLE TYPE	DIMENSIONS (mm)									TRAILER			TRACTOR		
	A	B	C	D	E	F	G	H	J	No. OF AXLES (N)	SELF WEIGHT (tonne)	PAYLOAD (tonne)	AXLE LOAD (tonne) X	AXLE LOAD (tonne) Y	TOTAL WEIGHT (tonne)
B1	8000	13650	5500	1600	4400	1020	900	2700	1850	12	90	310	18.3	10.0	46.6
B2	10570	0	4775	1500	6250	1020	900	2700	1850	15	50	210	9	6	24.0

Figure 11.2-5 Special Trucks Type A and Type B

11.2.3 General Specification for Roads

As mentioned earlier, the General Specification for Roads was issued in 1994. The specification is classified to eighteen (18) major sections having the numbering from 100 to 1800 and Standard Bill of Quantities. The main contents are presented hereafter:

1) Specification

100) General
200) Earthwork
300) Granular and Stabilized Subbase, Base Course and Stabilized Subgrade
400) Bituminous Pavement
500) Concrete and Concrete Structures
600) Structural Steel
700) Paint
800) Drainage and Surface Ducts
900) Slope Protection and Stabilization
1000) Piling
1100) Bridge Bearings, Expansion Joints, Joint Seals and Fillers
1200) Sidewalks, Paved Areas and Curbs
1300) Safety Barriers, Delineators and Fences
1400) Highway Signs and Road Markings
1500) Electrical Installations
1600) Landscape and Irrigation
1700) Utilities
1800) Plant and Equipment

8) Standard Bill of Quantities

Preamble to the Bill of Quantities
Bill 1- Preliminaries
Bill 2- Earthwork
Bill 3- Granular and Stabilized Subbase, Base Course, and Stabilized Subbase
Bill 4- Bituminous Pavement
Bill 5- Concrete and Structures
Bill 6- Incidental Construction
Bill 7- Electrical Installations
Bill 8- Landscape and Landscape Irrigation
Bill 9- Relocation of Utilities
Bill 10- Dayworks

11.3 PRELIMINARY PROJECT COST ESTIMATE

11.3.1 Procedure of Project Cost Estimate

The procedures of project cost estimate that has been adopted during the Master Plan (M/P) and Preliminary Feasibility Study (Pre-F/S) stages are shown in Figure 11.3-1. During the M/P stage only the unit costs per km in case of roads (or per meter for bridges) for the different construction items are required. Therefore, the recent and on-going project bid prices are utilized to estimate construction cost for each type of construction work. In the case of Pre-F/S, more accurate estimate is required. Therefore, the estimate should be based on the unit prices of construction material, labor costs and equipment costs. The estimate of these unit prices were obtained from the survey of the current market prices and analysis of the latest bid prices. Engineering services cost will be estimated by using the percentage of construction cost. ROW acquisition cost for new roads and widening are estimated by the prevailing land price. The exchange rates on Nov. 2004 were: US$ 1.0 = RO 0.384 = JPY 110.

11.3.2 Unit Prices of Major Construction Items

Unit prices of major construction materials, labor cost and equipment cost are shown in Tables 11.3-1, 11.3-2 and 11.3-3, respectively based on the investigation of the latest bid and market prices.

The major construction items are defined from the Sultanate of Oman, General Specification for Roads, April 1994 and their unit costs are presented in Table 11.3-4.

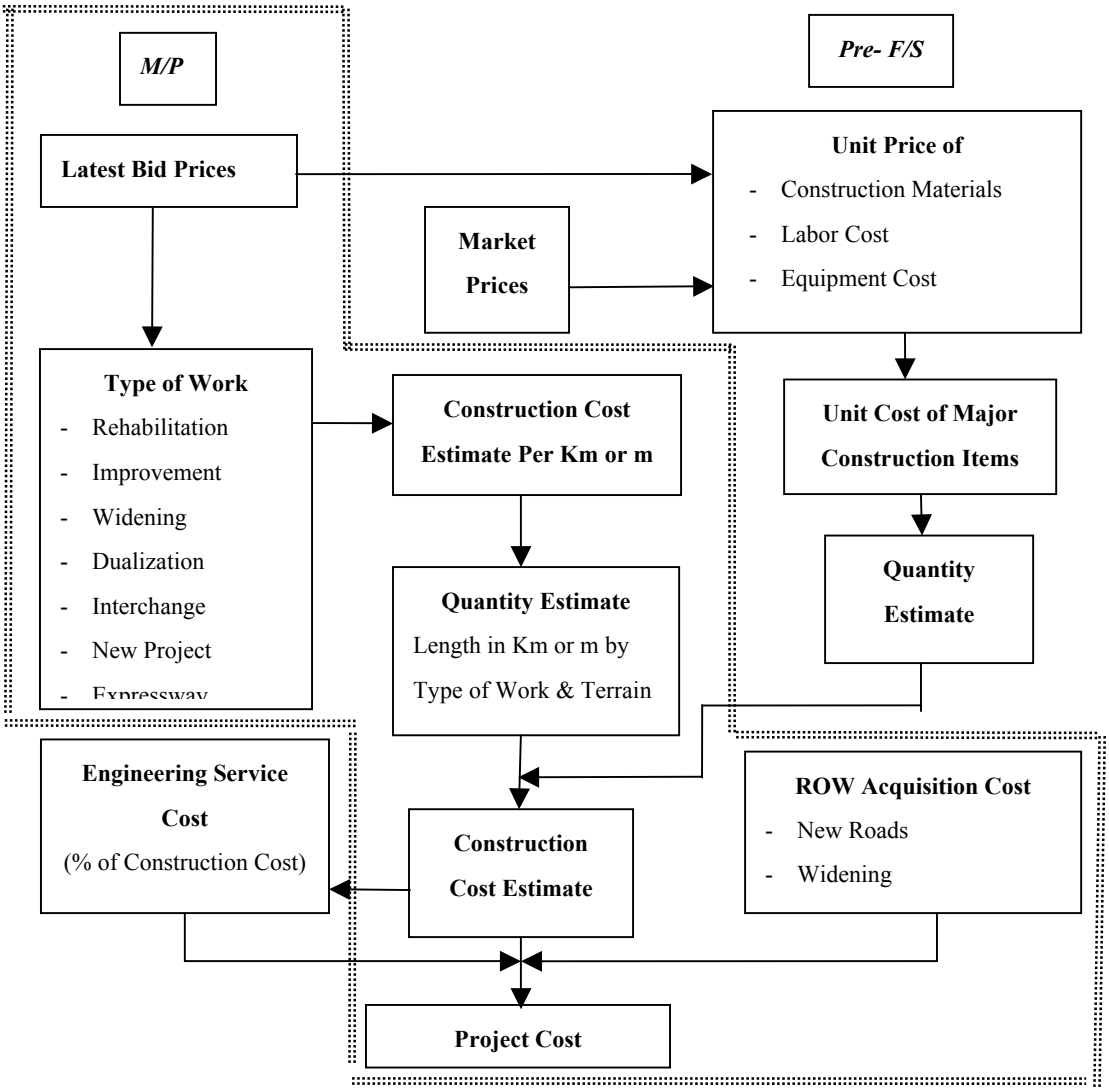


Figure 11.3-1 Procedure of Project Cost Estimate

Table 11.3-1 Average Prices of Major Construction Materials (2004 Prices)

No.	Material Description	Unit	Unit Price (RO)
1	Aggregates for granular sub-base course	Cu.m.	3.000
2	Aggregate for aggregate base course	Cu.m.	3.000
3	Aggregates for bituminous base course	Cu.m.	3.000
4	Fine aggregate for concrete	Cu.m.	4.000
5	Coarse aggregate for concrete	Cu.m.	3.500
6	Stone for drainage, masonry and slope protection	Cu.m.	3.000
7	Asphalt cement, grade 60-70 on site	Ton	90.000
8	Asphalt cement, grade 50-60 on site	Ton	80.000
9	Emulsified asphalt, grade RS-1 on site	Ton	100.000
10	Cutback asphalt, MC and RC type on site	Ton	100.000
11	Portland cement on site	Ton	25.000
12	Deformed billet steel bars, AASHTO M31 grade 60 (High Yield) of any diameter	Ton	250.000
13	Deformed billet steel bars, AASHTO M31 grade 40 (High Yield) of any diameter	Ton	225.000
14	Highway signs	Sq.m.	50.000
15	Highway sign support	Nr.	25.000
16	Timber plank, on site	Cu.m	150.000
17	Timber props, on site	Cu.m.	150.000
18	Wire mesh gabion, on site	Ton	225.000
19	Explosive, on site	Kg	50.000
20	Gas oil, on site	Liter	0.500
21	Gasoline, Premium	Liter	0.120
22	Gasoline, Regular	Liter	0.114
23	Diesel	Liter	0.102

Source: Study Team Survey

Table 11.3-2 Labor Cost (2004 Prices)

No.	Labor Category	Unit	Unit Rate (RO)
1	Supervisor	Hour	3.000
2	Site Surveyor	Hour	3.000
3	Foreman	Hour	2.000
4	1st Class Operator	Hour	2.000
5	2nd Class Operator	Hour	1.800
6	Mechanic	Hour	1.700
7	Driver	Hour	1.800
8	Skilled Labor	Hour	1.200
9	Semi-skilled Labor	Hour	1.000
10	Mason	Hour	1.200
11	Painter	Hour	1.200
12	Carpenter	Hour	1.200
13	Steel Fixer	Hour	1.200
14	Electrician	Hour	1.200

Source: Study Team Survey

Table 11.3-3 Hourly Cost of Major Construction Equipments (2004 Prices)

No.	Construction Equipment	Hourly Cost (RO)
1	Motor grader from 100 HP to 120 HP	12.000
2	Motor grader from 120 HP to 150 HP	15.000
3	Tractor from 60 HP to 100 HP	12.000
4	Bulldozer with ripper from 100 HP to 150 HP	12.000
5	Bulldozer with ripper from 150 HP to 200 HP	16.000
6	Bulldozer with ripper from 200 HP to 250 HP	18.000
7	Bulldozer with ripper from 250 HP to 300 HP	20.000
8	Wheel Tractor up to 50 HP	8.000
9	Wheel Tractor over 50 HP	9.000
10	Motor scraper capacity up to 18 cu.m.	18.000
11	Motor scraper capacity 18 to 24 cu.m.	22.000
12	Sheeps foot roller from 5 to 10 ton	7.000
13	Vibratory compactor with prime mover up to 5 ton	5.000
14	Pneumatic compactor with prime mover from 30 to 50 ton	5.000
15	Pneumatic self-propelled roller from 15 to 20 ton	6.000
16	Tandem roller up to 8 ton	5.000
17	Tandem roller from 8 to 12 ton	7.000
18	Triaxle roller from 10 to 15 ton	8.000
19	Light frog-rammer 0.1 ton	1.000
20	Heavy frog-rammer 0.5 ton	1.500
21	Wheel loader 1.2 to 1.6 cu.m.	6.000
22	Wheel loader 1.6 to 2.5 cu.m.	8.000
23	Excavator up to 0.8 cu.m.	6.000
24	Excavator from 0.8 to 1.2 cu.m.	9.000
25	Bituminous mixing plant with batching apparatus up to 80 ton/hr	20.000
26	Bituminous mixing plant with batching apparatus 80 to 150 ton/hr	30.000
27	Finisher up to 80 ton/hr	10.000
28	Finisher from 80 to 120 ton/hr	12.000
29	Bitumen sprayer up to t ton	7.500
30	Tanker truck up to 6 cu.m.	5.500
31	Dump truck up to 10 ton	5.000
32	Dump truck from 10 ton to 15 ton	6.000
33	Screening plant from 80 to 100 ton/hr	18.000
34	Crushing plant up to 40 ton/hr	13.000
35	Crushing plant from 40 to 60 ton/hr	15.000
36	Air compressor up to 6000 l/m	2.500
37	Air compressor over 6000 l/m	4.000
38	Mechanical broom	4.000
39	Power water pump	1.500
40	Steel cutting machine	1.000
41	Steel bending machine	1.000
42	Belt conveyor	2.000
43	Concrete mixer up to 0.5 cu.m.	2.500
44	Concrete mixer over 0.5 cu.m.	4.000
45	Automatic concrete batch plant without mixing	16.000
46	Transmixer up to 5 cu.m.	15.000
47	Concrete vibrators	1.000
48	Crane up to 5 ton	5.000
49	Crane with boom and jib from 5 to 10 ton	10.000
50	Crane with boom and jib over 10 ton	15.000
51	Generator 60 ~ 75 Kw	2.500
52	Generator 100 Kw	5.000
53	Generator 150 ~ 200 Kw	9.000
54	Drilling Equipment	10.000
55	Gravel strewer	5.000
56	Asphalt cutter	2.000
57	Vehicle for foreman and surveyor	5.000

Source: Study Team Survey

Table 11.3-4 Unit Cost of Major Construction Items

No.	Material Description	Unit	Unit Price (RO)
300	**Granular and Stabilized Subbase, Basecourse and Stabilized Subgrade**		
302	Class A Subbase	Cu. m.	5.000
	Class B Subbase	Cu. m.	4.000
	Class C Subbase	Cu. m.	3.000
303	Class A Basecourse	Cu. m.	5.000
	Class B Basecourse	Cu. m.	4.000
	Class C Basecourse	Cu. m.	3.000
400	**Bituminous Pavement**		
401	Prime Coat such as MC70	Kg	0.120
	Tack Coat such as RC250	Kg	0.150
402	Bituminous Basecourse	Cu. m.	17.000
405	Bituminous Wearing Course	Cu. m.	17.000
500	**Concrete and Concrete Structure**		
504	Concrete Class 28/20	Cu. m.	40.000
	Concrete Class 32/20	Cu. m.	45.000
	Concrete Class 36/20	Cu. m.	50.000
509	Reinforcing Steel		
	High yield steel bars	ton	250.000
	Mild steel bars	ton	250.000
800	**Drainage and Surface Ducts**		
801	Reinforced Concrete Pipe Culvert 750 mm	Lin. m.	50.000
	Reinforced Concrete Pipe Culvert 900 mm	Lin. m.	75.000
	Reinforced Concrete Pipe Culvert 1050 mm	Lin. m.	100.00
805	Waterproofing, bituminous paint	Sq. m.	0.500
900	**Slope Protection and Stabilization**		
901	Riprap		
	Loose stone riprap Class A	Cu. m.	6.000
	Loose stone riprap Class B	Cu. m.	6.000
	Mortared stone riprap	Cu. m.	15.000
902	Gabions	Cu. m.	13.000
903	Slope Netting (wire netting slope protection)	Sq. m.	1.700
904	Steel rock bolt (25mm dia., up to 5m long)	Lin. m.	18.000
	Steel rock dowel (25mm dia., up to 5m long)	Lin. m.	20.000
906	Ditch lining (150mm thick)	Sq. m.	2.000
907	Fabric permeable membrane	Sq. m.	0.600
1100	**Bridge Bearings, Expansion Joints, Joint Seals and Fillers**		
1101	Bridge bearing		
	Elastomeric bearing vertical capacity 1300 KN	Nr.	75.000
	Elastomeric sliding bearing vertical capacity 1300 KN	Nr.	165.000
1102	Expansion joint with movement range of 80mm	Lin. m.	160.000
	Expansion joint with movement range of 160mm	Lin. m.	210.000
	Expansion joint for RCBC, 20mm thick	Lin. m.	10.000
1200	**Sidewalks, Paved Areas and Curbs**		
1202	Curbs		
	Precast concrete curb, Class 28/20 non-mountable type	Lin. m.	5.00
	Precast concrete curb, Class 28/20 mountable type	Lin. m.	5.00
	Precast concrete curb, Class 28/20 lip type	Lin. m.	5.00

1300	**Safety Barriers, Delineators and Fences**		
1301	Corrugated Steel Beam Safety Barrier		
	Safety barrier beam (Class B, W-section)	Lin. m.	5.000
	Safety barrier post (Type C) including foundation	Nr.	12.000
	End anchorage (ramp down), including post (Type C) and foundation	Nr.	25.000
	W-beam terminal section		
	Re-fixing of safety barrier beam	Nr.	15.000
	Re-fixing of safety barrier post including foundation	Lin. m.	0.500
	Re-fixing of end anchorage (ramp down) including posts	Nr.	3.000
	Re-fixing of W-beam terminal section	Nr.	16.000
1302	Concrete safety barrier		
	Concrete safety barrier (Type A)	Lin. m.	55.000
	Concrete safety barrier (Type B)	Lin. m.	30.000
	Concrete safety barrier (at bridges)	Lin. m.	38.000
1303	Reflectorized Markers for safety barriers		
	Reflectorized markers (red) attached to Guardrail	Nr.	4.000
	Reflectorized markers (red) attached to concrete barrier	Nr.	3.000
1304	Delineators		
	Flexible delineators	Nr.	12.000
	Irish crossing markers	Nr.	35.000
	Irish crossing water depth gauges	Nr.	42.000
1400	**Highway Signs and Road Marking**		
1401	Highway Signs		
	Triangular, side 900mm	Nr.	25.000
	Triangular, side 1100mm	Nr.	30.000
	Triangular, side 1200mm	Nr.	40.000
	Circular, diameter 900mm	Nr.	30.000
	Circular, diameter 1200mm	Nr.	85.000
	Octagonal, side 900mm	Nr.	30.000
	Rectangular sign	Sq.m.	50.000
	Highway sign No. 202 (Stop Sign)	Nr.	30.000
	Highway sign No. 151 (Sharp Deviation)	Nr.	95.000
	Kilometer post (sign No. 323)	Nr.	25.000
	Sign post support assembly, (Type 1A)	Nr.	25.000
	Sign post support assembly, (Type 1B)	Nr.	54.000
	Sign post support assembly, (Type II)	Nr.	68.000
	Sign post support assembly, (Type IIIA)	Nr.	150.000
	Sign post support assembly, (Type IIIB)	Nr.	155.000
	Re-fixing of removed highway sign (any size with single post)	Nr.	20.000
	Re-fixing of removed highway sign (any size with multiple post)	Nr.	25.000
1402	Road Marking		
	Traffic lines (mechanically sprayed)	Sq. m.	1.600
	Special markings (hand sprayed)	Sq. m.	5.000
	Curb painting (black and yellow)	Sq. m.	1.000
	Reflecting road studs (double face)	Nr.	3.500

Source: Study Team Survey

Abovementioned data will be analyzed in the later stage of this Study in the cost estimation of the selected high priority projects.

The following section describes the estimation of unit cost per km or m for different type of projects such as paving of existing track roads, dualization of 2-lane roads,

widening, etc. that will be used for estimation of the construction cost of Master Plan projects.

11.3.3 Construction Cost Per Km

Table 11.3-5 shows the estimated cost per km of 15 recent projects (2000-2004) based on the data obtained from DGR. These projects were selected to represent the different regions within the Sultanate of Oman and also the cases of new construction, widening, dualization and rehabilitation. The estimated costs show that there is insignificant difference among the different regions. However, there is a significant difference in the unit cost regarding the condition of the terrain where the road traverses. The cost for mountain terrain is more than three times of that for flat terrain. The costs shown are representing the total of direct costs (Materials, Labors and Equipments) and indirect costs (Engineering and Contingency). The contingency is about 10% while the ratios of engineering detail design and construction supervision are about 3% and 4%, respectively.

Tale 11.3-5 Cost per km of Recent Projects

No.	Name	Region	Length (km)	Width (m)	Cost (1000 RO)	Remarks	Unit Cost (RO 1000 /km)
1	Quriyat-Sur Road Stage II, 2003, Section 1	As Sharqiyah	60.000	4x3.65m	33,493	Dual 4-lane	558
2	Rehabilitation Works for Nizwa-Thumrayt Road, Stage II, 2003	Ad Dhakhliyah Al Wusta Dhofar	292.000	2x3.75	13,836	Rehabilitation	47
3	Design and Construction of Paved Road Connecting Khaluf Village To Duqum-Sinaw Main Road, 2002	Al-Wusta	27.000	2x3.5m	1,385	New	51
4	Construction of Rustq-Miskin Road, 2002	Al Batinah	84.860	2x3.5m	9,500	New (rolling/ mountain)	112
5	Road Connecting Sohar Port to Ad Dhahirah Region, 2002	Al Batinah	145.685	2x3.5m	9,000	New	62
6	Construction of Wadi Andam including with Link Road to Al Qaryatain, 2002	Ad Dhakhliyah	43.188	2x3.5m	2,500	New	58
7	Birkat Al-Mawz Saya Road, 2002	Ad Dhakhliyah	5.000 12.480	2x3.5m	1,225 1,583	New (very steep mountain) (mountain)	245 126
8	Rehabilitation of Batinah Highway Al Wajajae to Bait Al Barakah Southern Carriageway, 2001	Al Batina	250.575	4x3.75	8,155	Rehabilitation	32
9	Construction of Wadi Al Ala and Wadi Al Ayn Roads, Stage I, 2001	Ad Dhakhliyah	13.900	2x3m	834	New	60
10 11	Dualization of Ibri-Hafeet Road, Phase-II, 2001	Ad Dhakhliyah	42.000 72.000	2x3.75m	4,186 6,736	Option 1 Option 2 Dualization	100 94
12	Construction of Tana'am Ramlat Khailah Road-Adhahira Region, 2001	Ad Dhahirah	148.000	2x3.75m	8,500	New	57
13	Rehabilitation of Bidbid Sur Road, Stage-I, 2000	Ad Dhahirah	30.000	2x3.5m	2,355	Rehabilitation	78.5
14	Quriyat-Sur Road Stage II, Alternative II, 2003, Section 2	As Sharqiyah	30.000	4x3.65m	22,493	New	750
15	Annual Track Roads Maintenance Project in Al Batina Region, 2001	Al Batinah	4098.10	6 to 9 m	187.580/km 178.186/km 168.789/km	Rehabilitation of Track Road 1 year contract 2 year contract 4 year contract	

Source: Study Team analysis based on DGR recent Bid prices.

Table 11.3-6 presents the list of the projects submitted recently (Feb., 2004) to Abu Dubai Development Fund. The list includes 7 projects among which two are dualization projects while the others are improvement of 2-lane unpaved roads to AC paved roads. The unit costs per km for the different projects are estimated as shown on the last column of the table.

Table 11.3-6 List of Projects Submitted To Abu Dubai Development Fund

No.	Project Name	F/S	Biding	Cost (Million RO)	Length (km)	Unit Cost / km (RO 1000)
1	Dualization of Ibri-Nizwa	3/3/04	Aug. 2004	30	130	230
2	Dualization of Nizwa-Thamarit	11/11/02	Mar. 2004	105 New 30 Reh Total 135.0	864	156
3	Thamarit-Marmul Road	On-going	Ready	5.4	90	60
4	Pave of Al Ashkhara-Shanah	31/3/2004	Jun. 2004	12.0	-	-
5	Pave of Marmul-Shalim-Sharbithat-Sukarah	On-going	Ready	7.0	141	50
6	Pave of Salim-Al Shuwaymiyah	On-going	Ready	2.6	47	55
7	Al Hamarah-Al Rustaqu Road 1st Stage 9 km, 2nd Stage 36 km	On-going	-	15	-	-
	Total	-	-	207.0	-	-

Source: Study Team Estimate based on MOT&C Report about Meeting of New Projects Submitted to Abu Dubai Fund, Feb. 9, 2004.

From the estimated unit costs shown in tables, unit costs per km for the major road constructions on flat terrain can be proposed approximately as follows:

Table 11.3-7 Unit Cost for Flat Terrain

Project Type	Cost (RO/km)
New Dual 4-Lane	400,000
Improve 2-Lane to Dual 4-Lane	100,000
New 2-Lane	70,000
Rehabilitation of 2-Lane (AC overlay)	20,000

The abovementioned costs are compared with the estimated costs presented in "Highway Master Plan 1986-1990" and "Feasibility Studies of Road Projects (Fourth 5-Year Plan), Jan. 1992". Unit costs presented in the Highway Master Plan 1986-1990 show that the unit cost per km of construction 2-lane paved road in case of flat terrain was about 120,000 RO. The cost as mentioned in the F/S of Road Projects 1992 was

about 90,000 to 100,000 RO. The cost derived from recent cases is about RO 70,000. The sequence of these figures shows a dropping trend.

One of possible reasons for the downward trend in construction cost is the extraordinary rise in construction costs due to the construction boom caused by construction of facilities for 1st GEC Conference held in the Sultanate in 1986. The Study Team can conclude that this trend might be due to the flowing reasons:

(1) The insufficient capabilities of the contractors 15~20 years ago, especially construction equipment that made prices went higher since they had to buy these expensive equipments: Recently, the contractors almost be in possession of such equipment and do not need to charge high cost for these equipments.
(2) Recent severe competition among contractors: Contractors are forced to offer lower price.

Therefore, the current costs are considered to be the minimum costs. The current low costs, on the other hand are suspected to be almost equal to the costs that the contractors are actually paying and yield very little profit. Therefore, it is anticipated that the current costs will go higher in future to give the reasonable profit margin to contractors. In order to make conservative estimate for the future required funds, the current rates should be increased by about 10%. If this concept will be considered, the unit cost/km of new 2-lane AC paved road as an example will be about RO 77,000.

Based on comparison of the unit costs per km for different terrains, it can be concluded that the ratios of unit costs per km among different terrains are as presented in Table 11.3-8.

Table 11.3-8 Ratios of Unit Cost per km for Different Terrains

Terrain	Flat	Rolling	Mountainous
Ratio (New Construction/Widening)	1.00	1.75	3.50
Ratio (Rehabilitation/Improvement)	1.00	1.20	1.30

The estimated costs by the recent bid prices and the estimated unit costs of major construction items are utilized to prepare the reasonable construction cost per km for each type of works as shown in Table 11.3-9 taking into consideration the above mentioned cost analysis.

Table 11.3-9 Construction Cost per km (RO 1000)

Type of Work	Abbreviation	Description of Work	2-lane			4-lane		
			Flat	Rolling	Mountain	Flat	Rolling	Mountain
Rehabilitation	RH AC R	AC pavement reconstruction	33	39	43	66	79	86
	RH AC O	AC overlay	22	26	29	44	53	57
	RH PC R	PCC reconstruction	44	53	57	88	105	114
	RH T R	Track road (km/ year)	0.198	0.238	0.257	-	-	-
Improvement	IM 2LTR PR	2-lane track road to paved road	44	53	57	-	-	-
	IM SH W	Shoulder widening	11	19	38	11	19	38
Traffic Capacity Expansion	TCE W 6L	Widening 4-lane to 6-lane	88	154	308	-	-	-
	TCE D 4L	Dualization 2-lane to 4-lane	88	154	308	-	-	-
	TCE IC	Interchange	-	-	-	3,300 ~ 3,800	-	-
New Projects	NP 2L	2-lane highway	77	135	270	-	-	-
	NP 4L	4-lane highway	-	-	-	154	270	539
	NP EXP	Expressway	253	443	885	495	866	1732

Source: Study Team Estimate

Unit Costs For Bridges And Culverts

The unit costs for bridges and culverts are estimated as presented in Table 11.3-10.

Table 11.3-10 Bridges and Culverts Unit Cost

Item	Cost (RO 1000)
R.C. 2-lane bridge low level	3.0 / lin. m.
	3.8 / lin. m.
R.C. 2-lane bridge high level	4.2 / unit
R.C. Box Culvert Single Cell	7.6 / unit
R.C. Box Culvert 2-Cell	10.0 / unit
R.C. Box Culvert 3-Cell	2.9 / unit
R.C. Pipe Culvert Complete Standard Diameter	5.8 / unit
R.C. Pipe Culvert Complete Large Diameter	0.5 / lin. m.
R.C. Irish Crossing 7.5m Pavement Width	0.018 / km
Drainage Repair, Irish Crossing Repair and Miscellaneous Minor Repairs	

Source: Study Team Estimate

Maintenance Cost

Routine and periodical maintenance are considered. The cost of routine maintenance is presented in Chapter 13 and is assumed to start the following year to the opening of the project.

The periodical maintenance is consisting of two components that AC overlay for asphalt pavement every 10 years and maintenance to bridges also every 10 years. AC overlay is estimated by applying a unit rate of asphalt structure to estimate the total cost of overlay

of the whole road. In case of bridge an average of 50,000 RO is estimated to be required every 10 years.

11.3.4 Indirect Cost

Indirect cost is composed of overhead and other miscellaneous. These expenses are estimated as percents of the direct cost and generally vary directly with the magnitude of the estimated direct cost.

Indirect cost will be considered on the final stage of the study for the specified high priority projects subjected to pre-feasibility study.

For M/P the estimated unit cost per km is already included the direct and indirect costs since it estimated from the average of the on-going and recent bid prices.

11.3.5 Engineering Service Cost

The Engineering cost covering detailed engineering design and construction supervision is estimated as a certain percent of the project construction cost. The investigation of the recent projects in the Sultanate of Oman shows that the current percents for D/D and C/S are about 3% and 4%, respectively.

11.3.6 Land Acquisition

This subsection is prepared to summarize the major land acquisition items based on the 2003/2004 land acquisition costs, Royal Declare No. 4/2003, issued on the Gazette No. 753.

1) General Rules

a- Compensate for acquired land by providing substitutive land equivalent in area and in the same region. In case that equivalent land cannot be provided in the same region, another available land in any other region will be given taking into consideration to compensate the difference on the land price.
b- In case that the given land area is greater than the acquired area, the citizen will be charged for the price difference based on the rate of the governmental land prices. In case that no substitutive land is available, cash payment will be made based on the following rules.
c- For residential areas smaller than 400 m^2 which is totally affected, the owner can chose between two alternatives; 1) get substitute land and pay the difference in the

land price, and 2) cash payment compensation based on the market prices mentioned hereafter. However, the minimum compensations are:

Muscat except Qurait and Amarat Wilayats and
Salalh Governorates: RO 5,000

Other Governorates and Qurait and Amarat Wilayats: RO 3,000

d- Market prices of agricultural areas outside Muscat Governorate and the coastline from Salalah to Taqah City within Dhofar Governorate are shown in Table 11.3-11.

Table 11.3-11 Compensation of Agricultural Areas

Classification	Price (RO/m^2)
Productive agricultural area	1.190 – 2.020
Cultivated agricultural area	0.238 – 0.595
Uncultivated agricultural area	0.119 – 0.238

e- In case of agricultural land acquisition in Muscat Governorate and the coastline from Salalah to Taqah City within Dhofar Governorate, the land pricing committee should prepare a proposal for each project and submit it to the Technical Secretariat of Supreme Committee for Town Planning.

2) Compensations

The compensation of the residential and commercial areas shall be estimated by Property Appraisal Committee based on the attached pricing lists to the Royal Declare No. 4/2003. The average prices of these lists for major regions are summarized as shown in item 3 below.

3) Market Prices of Lands

Range of market prices of residential and commercial areas at major regions are presented in Table 11.3-12. The big ranges of prices are due to the large differences of the land prices among the different Wilayats even they are located within the same region.

4) Estimation of Building and Crops Compensations

It was issued on the same Gazette No. 753, the Royal Declare No. 5/2003 concerning the Building and Crops Compensations.

Table 11.3-12 Compensations of Residential and Commercial Areas (RO/m^2)

Governorate	Residential	Commercial
Muscat	2 - 35	3 - 50
Al Batinah	3 - 8	5 - 12
Musandam	2 - 15	3 - 25
Ad Dhairah	2 - 5	5 - 40
Ad Dhakhliyah	3 - 25	5 - 40
As Sharqiyah	2 - 25	3 - 40
Al Wusta	1 - 6	1 - 10
Dhofar	1 -40	2 - 80

5) Right of Way (ROW)

Securing the ROW of 120 m or more for the major roads of Sultanate of Oman is issued on the HDM Vol. 1 Appendix A. Table 11.3-13 presents the right of way stipulated in HDM for some of the major numbered roads.

Table 11.3-13 List of Roads with ROW 120 m Wide or More

Route Number	Location	Width of Right of Way
1	Muscat to Khatmat Milahah	120 in open country; minimum of 107 where established in towns.
2	Daba al Bayah – Khasab –Dhora	120 m.
4	Muscat to Wadi Hatta (Second Batinah Highway)	500m (to include for railway).
5	Aqr-United Arab Emirates	120 in open country; reduced width in existing towns.
7	Sohar to Al Buraymi	120 in open country; reduce ed width in existing towns.
9	Al Khaburah to Miskin Miskin to Ibri	120m. 120 in open country; reduced width In towns (50m agreed in Ibri).
15	Muscat to Firq	120 in open country; minimum of 107m where established in towns.
17	Muscat to Qurayyat Qurayyat to Sur	120 in open country; minimum of 107m where established in towns. 120m.
21	Jabrin to Al Buraymi	120 in open country; reduced width in existing towns.
22	Firq to Jabrin	120m.
23	Bidbid to Sur	120 in open country; minimum of 107m where established in towns.
28	Ash Sharqiyah region to Ad Dakhliyah region	120m
31	Firq to Adam Adam to Thumrayt Thumrayt to Salalah	200m. 400m. 120 in open country; reduced width in existing towns.
35	Al Wafi to Al Ashkharah	120 in open country; minimum of 107m where established in towns.

11.3.7 Estimated Project Costs

Costs for the proposed Development Projects described in Section 10.1 were estimated using the unit costs described above. The estimated costs for the proposed Development Projects are shown in Table 11.3-14.

Table 11.3-14 Estimated Cost for Proposed Projects (1/2)

Project No.	Project	Improvement Type	Length km	Cost RO '000
1. Roads				
	On-going Major Projects			
	Rustaq - Miskin (to 2006)	2-L	[76]	*[9,504]*
	Quriyat - Sur II-1 (to 2007)	4-L	[60]	*[33,493]*
	Quriyat - Sur II-2 (to 2006)	4-L	[30]	*[22,737]*
N6	Al Ashkharah - Shanna	2-L	[164]	*[15,000]*
N9	Marmul - Shelim - Sharbithat - Sawqrah	2-L	[140]	*[6,800]*
N10	Shelim - Shuwaymiyah	2-L	[48]	*[3,265]*
N26	Thumrait - Marmul	2-L	[86]	*[5,438]*
N34	Tawi Attair-Jibjat	2-L	[41]	*[11,070]*
U	**Upgrading**			
U1	Batinah Highway	Culverts	270	29,120
W	**Widening**			
W1	Bait Al Barakah - Al Muladdah	4-L to 6-L	54	4,752
D	**Dualization**			
D2	Bidbid - Sur		277	29,713
D3	Nizwa - Bahla - Ibri		125	*26,500*
D4	Karsha - Al Ghaba - Thumrayt - Salalah		843	*92,510*
D5	Majis (Sohar) - Az Zarub - Buraymi		97	*43,838*
D6	Mizbar - Qaryatan - Izki		85	13,090
D7	Ma'mura - Taqah		20	*3,000*
D8	Muladdah- Hazm Road		24	2,112
D9	Quriyat - Sur Phase III		18	*4,886*
D10	Barka - Rustaq Road		84	9,042
D11	Ibri - Ad Dariz Road		19	1,672
D12	Taqah - Mirbat		37	*5,500*
D13	Raysut - Rakhyut		80	12,320
D14	Rakhyut - Yemen Border		45	6,930
D15	Dawkah - Al Mazyunah		226	19,888
D16	Izki - Thumrayt Coastal Road		1,007	110,000
D17	Ibri - Saudi Arabia		143	22,022
D18	Sohar - Ibri		162	49,896
D19	Rustaq - Ibri		136	41,600
N	**New Construction**			
N1	New Batianh Expressway	4-L	247	132,008
N3	Bait Al Barakah - Khatmet Malahah, Coastal	2-L	255	19,635
N4	Diba - Khasab		95	*25,441*
N5	Lima Link - Khasab		25	4,050
N7	Hasik - Shuwaymiyah		120	39,026
N11	Rakhyut - Dalkut Coastal Road		25	1,925
N12	Madinat AL Haq - Nashib		28	*3,000*
N13	Hujaif - Jahnin - Asir		22	*3,000*
N14	Teetam - Qaftut		12	*3,000*
N15	Haluf - Masahilah		12	*700*
N16	Dawkah - Shisur - Qafaa		165	*8,000*
N17	Wadi Haruf - Shisur		83	6,391
N18	Mudayy - Aybut - Aydam		74	*4,000*
N19	Al Mazyunah - Tawsinat - Habrut - Aydam		120	21,600
N20	Shahb Asayb - Rakhyut		16	4,320
N21	Dalkut - Khadrafi - Sarfait		14	3,780
N22	Al Mazyunah - Mitan		96	7,392

Table 11.3-14 Estimated Cost for Proposed Projects (2/2)

Project No.	Project	Improvement Type	Length km	Cost RO '000
N23	Hajaif - Masahilah		25	*1,300*
N24	Jibjat - Barbazum		65	17,550
N25	Haylat - Ar Rakah		25	1,925
N27	Hatt - Rustaq, Phase IV		28	8,417
N28	Yanqul - Fida - Dank		41	9,990
N29	Yanqul - Murry		26	7,020
N30	Madha - Dafta		15	5,146
N31	Amal - Muqshin		180	13,860
N32	Marmul - Dawkah		140	10,780
N33	Tiwi - Ismaiyah		60	16,200
N34	Tawi Attair-Jibjat		41	11,070
N36	Mahlah - Ghubrat at Tam - Ismaiyah		38	6,283
N37	Qaran - Maqal - Sabt - NR 23		55	11,955
N38	Al Mazari - Ghubrat at Tam		80	21,600
N40	Wadi Saa - Al Feth - Dank		80	21,600
N41	As Sunaynah - Al Feth - Al Wqba		45	7,230
N43	Al Wajajah - Ash Shwayhah		80	21,600
N44	Murri - Ar Rumaylah - Al Ayn		30	8,100
N45	Al Ayn - Sint - Al Wadi Al Ala		30	8,100
N46	Bahja - Amal		170	13,090
N47	Al Hij - Flim		19	1,767
N50	Flim - Mahowt (Box Culvert based on EIA)		6	9,000
N48	Qatbit - Al Mushash (Saudi Border)		152	6,688
N49	Al Ghaba - Ramlet Khaylah (Saudi Border)		298	13,112
N51	Aybut - Habrut		65	3,000
B	**Bypass**			
B1	Sinaw Bypass		6	924
B2	Ibri South Bypass	300m Tunnel	13	2,002
B3	Ibra Bypass		11	2,970
B5	Ibri East Bypass		10	1,540
B6	Salalah Outer Bypass		42	22,638
B7	Adam Bypass		5	770
B8	Al Kamil North Bypass		9	1,309
B9	Al Wafi East Bypass		11	1,694
2. Structures	(Grade Separation)			
G1	Naseem Garden		1	3,623
G2	Baraka Roundabout		1	3,688
G3	Al Muladdah Junction		1	3,609
G4	Khaburah Roundabout		1	3,812
G5	Saham Roundabout		1	3,849
G6	Sohar Roundabout		1	4,146
G7	Falaj Al Qabail		1	4,232
G8	Aqr Roundabout		1	3,298
P1/12	Pedestrian Crossing 1	12 Locations		1,380
P13/22	Pedestrian Crossing 2	10 Locations		1,150
Improvement	Bridge Repair			751
	Shoulder Improvement - Primary			7,892
	Shoulder Improvement - Secondary			1,620
	Black-spot Improvement			3,000
Total			**7,068**	**1,151,939**

Note: [ ] Lengths between brackets are not included

Costs in Italic are estimated by DGR / DGC

CHAPTER 12

INITIAL ENVIROMENTAL EXAMINATION

CHAPER 12

INITIAL ENVIRONMENTAL EXAMINATION

12.1 GENERAL

12.1.1 IEE Study

1) Objectives of the Initial Environmental Examination (IEE)

The objectives of the Initial Environmental Examination (IEE) are to understand the present environmental conditions of selected project roads, to identify the present impacts of each project road, to analyze environmental impacts based on the road design, alignment and future traffic volume, to evaluate comprehensively each project road, and to examine necessary possible mitigation plan and necessity of the Environmental Impact Assessment (EIA) in next stage. The workflow of IEE study is shown in Figure 12.1-1.

2) Methodology

The IEE study is carried out according to the following procedure:

a. Data Collection of Each Project Road

The road information and data of each road project, including road map, topographic map, geological map, road distance, road structure, cultural heritages, archeological information, ecological and biological data, present and future traffic volume, proposed road plan, and other necessary information, had been collected before the site investigation.

b. Site Investigation

The site investigation, which is carried out all the way along the project roads, consists of the following items:

1- Filling in the Environmental Checklist as shown in Table 12.1-1; interval of each checkpoint is 20 km distance in maximum or between main city/town/village, being less than 20 km distance as a road unit,

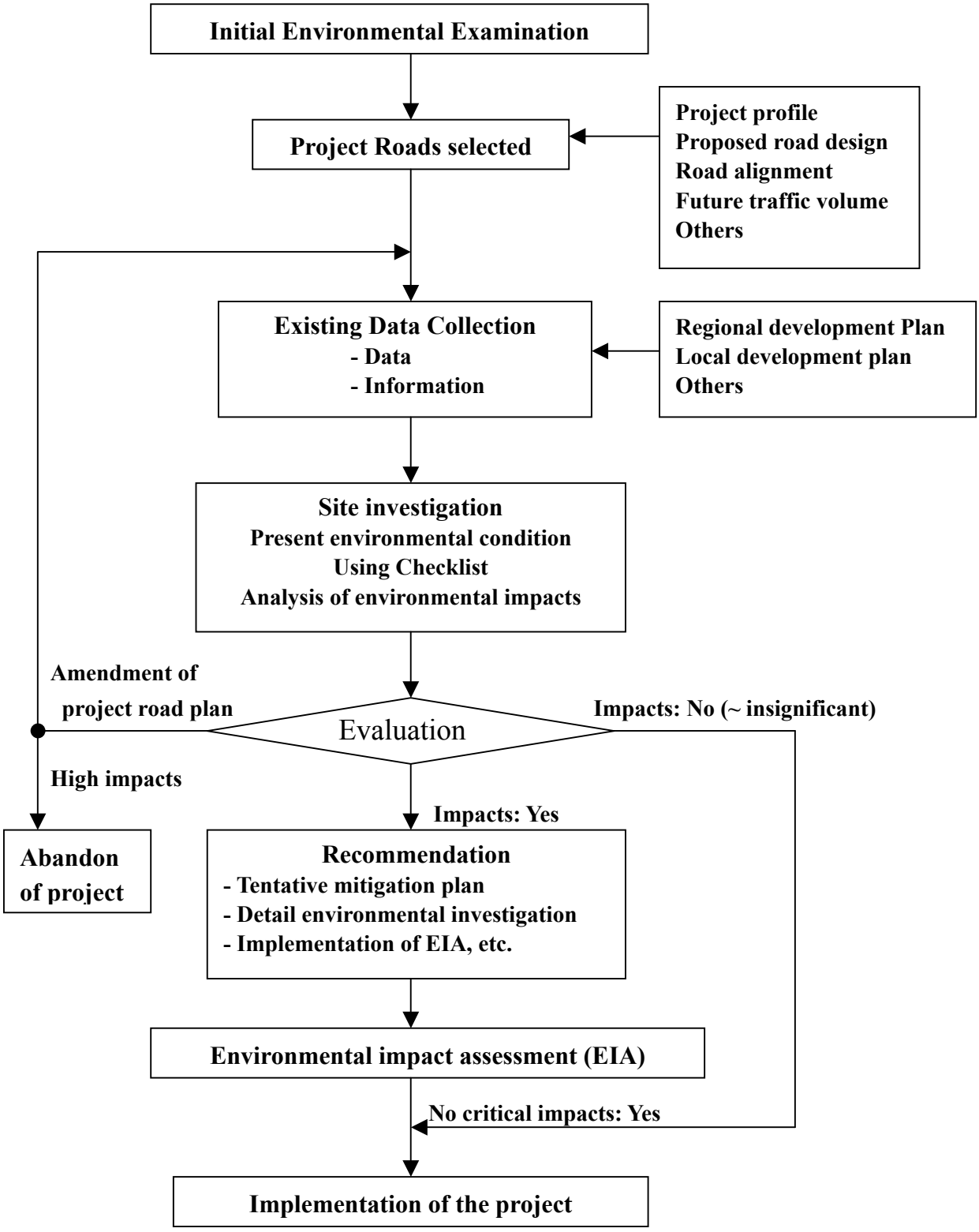


Figure 12.1-1 Flow of Initial Environmental Examination

2- Description of environmental public facilities (school, Wali office, mosque, electric sub-station, etc.), control points (bridge, dam site, fort, aflaj system, village, etc.), and other important infrastructures,
3- Interviews to inhabitants in the Study Area, if necessary, and
4- Taking photographs as the field evidences.

The content of the site investigation consists of the following environmental items:

1. Air pollution
2. Effluent
3. Noise and vibration
4. Land subsidence
5. Topography and geology
6. Soil and soil erosion
7. Hydrology and groundwater
8. Ecosystem, flora and fauna
9. Landscape (including coastal zone)
10. Regional development on the natural environment
11. Hazards
12. Other impacts on the natural environment
13. Wastes
14. Cultural heritage
15. Regional development on the social environment
16. Other impacts on the social environment

12.1.2 Selected Project Roads

Locations of the selected project roads are shown in Figure 12.1-2. Number and total length of the projects are 91 roads and 5,694 km, respectively.

12.1.3 Implementation of IEE Study

The IEE study using the environmental checklist was carried out from June 1st to June 25th, 2004.

Table 12.1-1 Environmental Checklist for IEE

ENVIRONMENTAL CHECKLIST (Project No.)

Road Section: _____, Existing road condition:_____

Project No.: __, National Road No. __, Planning road:_____, Distance: __km

Environmental Items	Present Condition (Description and Location Area of Concern)	Impact Rating: 1. Slight 2. Moderate 3. Significant	Remarks Future traffic volume in 2030: PCU/day
Natural Environment			
Air pollution (SO_2, NO_2, CO, SPM, Dust, etc.) How is present condition concerning the air quality? Is there a possibility that exhaust gases from passing vehicles will adversely affect local inhabitants? When there is already a factory zone that pollutes the air in the route vicinity, is there a possibility that opening the road to traffic will further exacerbate the impact of air pollution? During road construction, is there dust occurred from construction, quarry and borrow-pit sites? Do emitted air pollutants comply with the Oman's emission standards and environmental quality standards? Can the same be said for other air pollutants? Others.			
Effluent （Drainage from road facilities, SS, etc.） How is present condition concerning the water quality? Do effluents that contained SS and other pollutants discharged during construction stage? Do effluents comply with the Oman's effluent standards and environmental quality standards? Others.			
Noise and vibration (Likely receptors and current conditions.) How is present condition concerning the noise and vibration? Is there a possibility that, after opening the road to traffic, the noise and vibration of passing vehicles will have a significant impact on inhabitants? Is the country's noise and vibration standards complied with? Others.			
Land subsidence How is present condition concerning the land subsidence? In the soft ground and limestone areas, is there possibility to cause land subsidence along the project roads? Others.			

Topography and geology (Areas of concern with geology/ landslides, etc.) How is present condition concerning the topography and geology? Are there any places along the route with poor geology that might be subject to washouts or landslides? Have plans been made for land stability when changes such as embankments and cuts are made in the land? Has consideration been accorded to slope protection so as to prevent soil erosion on embankments and cuts? Has rainwater drainage been properly considered in order to prevent soil erosion? Others.			
Soil (Soil extraction, soil erosion, etc.) How is present condition concerning the soil and soil erosion? Have considerations been given to preventing soil runoff at disposal sites for surplus soil from cuts, or at soil extraction sites for the soil used in embankments? Have plans been made to prevent adverse environmental impacts at soil dumping sites and soil extraction sites? In and along the watercourses (wadis), is there a possibility of the soil erosion caused by crossing or intersection of the watercourses by roads? Others.			
Hydrology/groundwater How is present condition concerning the water, hydrology and groundwater? Is there a possibility that changes in groundwater systems including aflaj system by modifications in the land, or changes in surface river systems by the building of structures, will adversely affect the hydrology or water use? Others.			
Ecosystem, flora and fauna (Natural reserve/ endangered species/ valuable habitats, etc.) How is present condition concerning the ecosystem, flora and fauna? Does the project site encompass the endangered and valuable habitats of wildlife, or plants? Are there concerns about negative impacts on the ecosystem, such as destruction of forests and desertification? Others.			
Landscape (Sensitive areas, etc.) How is present condition concerning the landscape including coastal zone? Are adverse effects on landscape anticipated? In coastal zone, is there possibility of negative impacts on the landscape including valuable topography, mangrove, others?			

Hazards (Wadi flow, flash flood, sand storm, etc.) How is present condition concerning the hazards? Is there a potential to occur the disasters related to the roads consisting of traffic accidents by rainfall, traffic interruption and scouring, and bank erosion by flash flood along wadis, traffic interruption by sand storm and fog, slope failure (including land slide), interruption by sand dune, land subsidence in a limestone area, etc.? Others.			
Regional development on Natural Environment How is present condition concerning the regional development? Does road construction in undeveloped areas involve the possibility of major damage to the natural environment caused by new regional development after opening roads to traffic? Others.			
Other Impacts on Natural Environment Are other project specific negative impacts anticipated? If impacts are anticipated, has sufficient consideration been accorded to measures for the mitigation? Others.			
Social Environment			
Cultural heritage (Fort, ruin, etc.) How is present condition concerning the cultural heritage? Is there any possibility that the project will damage properties or historical sites that are of great historical, cultural, or religious value? Others.			
Wastes (Litter along the road, wastes during construction, etc.) How is present condition concerning the wastes? Has careful consideration been given to the methods for treatment and disposal of general wastes and industrial wastes? Do wastes comply with the country's standards? Others.			
Regional development on social environment (Division of community, traffic volume, etc.) How is present condition concerning the regional development? Does road construction in undeveloped areas involve the possibility of major impacts on the lives of local inhabitants due to new regional development after opening roads to traffic? Others.			
Other impacts on the social environment Are other project specific negative impacts anticipated? If impacts are anticipated, has sufficient consideration been accorded to measures for the mitigation? Others.			

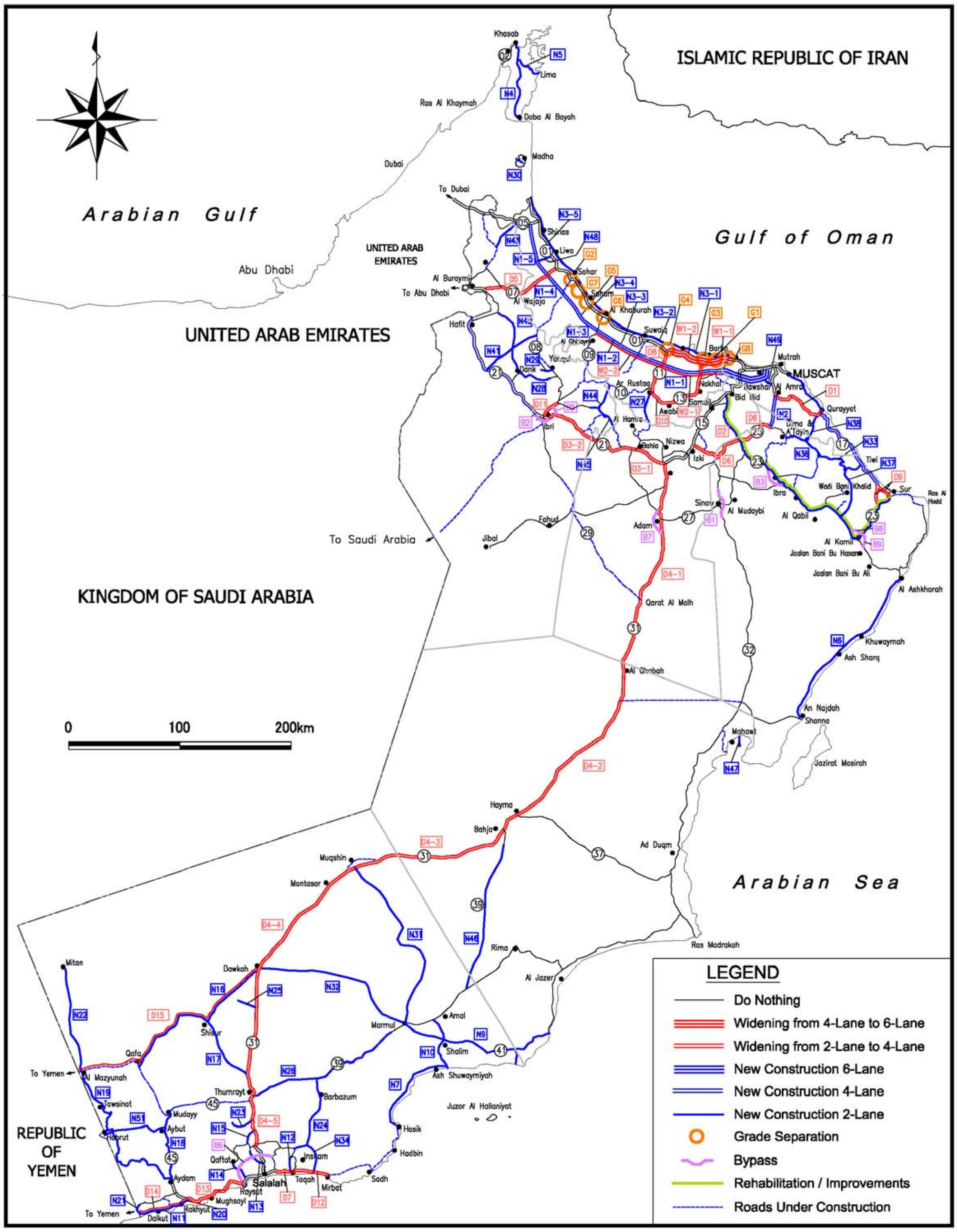


Figure 12.1-2 Location of Selected Project Roads

12.2 RESULTS OF IEE STUDY

12.2.1 Results of IEE

The environmental checklists, table and figure of the IEE results are shown in Appendix 12 –1, Table 12.2-1 and Figure 12.2-1, respectively.

The impact rating of each environmental item is classified into five classes, consisting of 1, 1~2, 2, 2~3 and 3 classes. Each class of impact to the environment is described as follows:

Class 1	: None to slight impact
Class 1~2	: Slight to moderate
Class 2	: Moderate impact
Class 2~3	: Moderate to significant impact
Class 3	: Significant impact

12.2.2 Comprehensive Evaluation of the Project Roads

The comprehensive environmental evaluation of the project was examined based on the present environmental condition, proposed project road design, future traffic volume, other development plan, etc. Results of the examination are shown in Table 12.2-1 (right side).

The evaluation rating is classified into five classes, consisting of 1, 1~2, 2, 2~3 and 3 classes same as impact rating for the environmental items. Each class of the evaluation is described as below.

Class 1: is thought to be acceptable, because of minimum impact to the environment.

Class 1~2: is slight to moderate impact to the environment, and the countermeasures for that impact might be relatively simple in general.

Class 2: is moderate impact to the environment, and the project area seems to be relatively sensitive environment. As the environment will be obviously/ potentially received serious influence, the countermeasures for the mitigation should be required.

Class 2~3: is moderate to significant impact to the environment, and the project area might be quite sensitive environment. As the environment will get a serious influence for relatively short time, the countermeasures for the mitigation should be required, and partial alteration of the project might be required as an alternative plan.

Class 3: is significant impact to the environment, and the project area generally might

be very sensitive environment. As the environment will be immediately get a serious influence for a short time, the countermeasures for the mitigation and alteration of the project as well as alternative plan should be required. In addition, one of the alternative plans includes abandon of the project.

Table 12.2-1 Comprehensive Evaluation of Initial Environmental Examination (1) ~ (9)

(1)

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation *1	Mitigation Measures
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
W1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	- Increased traffic volume.	**2**	-Traffic regulation in urbanized area.
W2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	- Increased traffic volume.	**2**	- Traffic regulation in urbanized area.
D2	1	1	1~2	1	1~2	1	1	2	1	1	1	1	1~2	1	1	1~2	- Increased traffic volume. - Alteration of topography. - Passing near As Saleel National Park.	**2**	- Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
D3	1	1	1	1	1	1	1	1~2	1	1	1	1	2~3	1	1	1~2	- Passing beside Bahla Fort (World Heritage). - Relocation of houses, mosque, etc.	**2~3**	- Adjusting of alignment.
D4-1	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	1	-Influence to cultural heritage.	**1~2**	- Adjusting of alignment. Site investigation for cultural heritage.
D4-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
D4-3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
D4-4	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	1	-Influence to cultural heritage.	**1~2**	- Adjusting of alignment.
D4-5	1	1	1~2	1	1~2	1~2	1	2	1	1	1	1	1~2	1	1	1~2	- Increased traffic volume. - Deforestation by excavation and embankment. - Increased accident of domestic animals, etc.	**2**	-Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.

***1:** **1:** Air Pollution, **2:** Effluent, **3:** Noise and Vibration, **4:** Land Subsidence, **5:** Topography and /Geology, **6:** Soil, **7:**Hydrology/ groundwater, **8:** Eco-system, Flora and Fauna, **9:** Landscape, **10:** Hazards, **11:** Regional Development on Natural Environment, **12:** Other Impacts on Natural Environment, **13:** Cultural Heritage, **14:**Waste, **15:** Regional Development on Social Environment, and **16:** Other Impacts on Social Environment.

(2)

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				5	6	7	8	9	10	11	12	13	14	15	16			
D5	1	1	1~2	1	2	1	1	2	1	1	1	1	1~2	1	1	2	- Increased traffic volume. - Alteration of topography. - Deforestation by excavation and embankment. - Increased accident of domestic animals, etc.	**2**	-Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.
D6	1	1	1	1	1~2	1	1	1~2	1	1	1	1	1	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Relocation of houses.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
D7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
D8	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	1~2	- Deforestation by excavation and embankment. - Influence to cultural heritage. - Increased accidents of domestic animals.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. Site investigation.
D9	1~2	1	1~2	1	1~2	1	1~2	1~2	1	1	1	1	1~2	1	1	1~2	- Increased traffic volume. - Alteration of topography - Deforestation by excavation and embankment. - Influence to cultural heritage. - Increased accidents of domestic animals.	**1~2**	Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. Site investigation. - Fencing for domestic animals.
D10	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	1~2	- Influence to cultural heritage. - Increased accidents of domestic animals.	**1~2**	- Adjusting of alignment. Site investigation. - Fencing for domestic animals.
D11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	- Relocation of some houses.	**2**	- Adjusting of alignment.
D12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1~2	- Increased accidents of domestic animals.	**1~2**	- Fencing for domestic animals.
D13	1	1	1	1	1~2	1	1	2	1	1	1	1	1	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Increased accidents of domestic animals.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.

(3)

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				5	6	7	8	9	10	11	12	13	14	15	16			
D14	1	1	1	1	2	1~2	1	2	1~2	1	1	1	1	1	1	2	- Alteration of topography. - Deforestation by excavation and embankment. - Relocation of houses.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
D15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N1-1	1~2	1	1~2	1	1~2	2	1~2	2	1	1	1	1	1	1	1	1~2	- Increased traffic volume. - Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage. - Increased accidents of domestic animals.	**2**	-Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. Site investigation. - Fencing for domestic animals.
N1-2	1~2	1	1~2	1	1~2	2	1~2	2	1	1	1	1	1	1	1	1~2	- Same as above.	**2**	- Same as above.
N1-3	1~2	1	1~2	1	1~2	2	1~2	2	1	1	1	1	1	1	1	1~2	- Same as above.	**2**	- Same as above.
N1-4	2	1~2	2	1	2	2	2	2	2	2	1	1	2	2	1	2	- Same as above.	**2**	- Same as above.
N1-5	1~2	1	1~2	1	1~2	2	1~2	2	1	1	1	1	1	1	1	1~2	- Same as above.	**2**	- Same as above.
N3	2	1	2	1	1~2	2	1~2	2	1	1	1	1	1	1	1	2	- Increased traffic volume. - Alteration of topography. - Deforestation by excavation and embankment. - Relocation of houses. - Increased accidents of domestic animals.	**2**	-Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. - Fencing for domestic animals.
N4	1	1	1	1	1~2	1	1	1~2	1	1	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. Site investigation.

(4)

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**			
N5	1	1	1	1	1~2	1	1	1~2	1	1	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. Site investigation.
N6	1	1	1~2	2	2	1	1	2~3	2	1~2	1	1	1~2	1	1	1	- Alteration of topography. - Influence to sand desert wildlife. - Permanent occurrence of sand storm. - Influence to cultural heritage.	**2~3**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N7	1	1	1	1	2	1	1~2	3	2	1	1	1	1	1	1	1	- Alteration of topography. - Influence of inlet and wadi mouths. - Passing in the Jabel Samhan Natural Reserve - Influence of mountainous and marine wildlife. - Influence to cultural heritage.	**3**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. - Examination of alternatives or abandon of project.
N9-1	1	1	1	1	1	1~2	1	1~2	1	1	1	1	1	1	1	1	- Passing near the Jabel Samhan Natural Reserve	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height.
N9-2	1	1	1	1	1	1	1	1~2	1	1	1	1	1	1	1	1	- Same as above.	**1~2**	- Same as above.
N10	1	1	1	1	2	1	1	2	2	1	1	1	1~2	1	1	1	- Alteration of topography. - Passing near the Jabel Samhan Natural Reserve. - Influence to cultural heritage.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N11	1	1	1	1	1~2	1~2	1	2	1~2	1	1	1	1~2	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage. - Relocation of houses.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				5	6	7	8	9	10	11	12	13	14	15	16			
N12	1	1	1	1	1	1~2	1	2	1~2	1	1	1	1	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N13	1	1	1	1	2	2	1	2	1~2	1	1	1	1~2	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage. - Increased accidents of domestic animals.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. - Fencing for domestic animals.
N14	1	1	1	1	2	2	1	2	1~2	1	1	1	1	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Increased accidents of domestic animals.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.
N15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1~2	- Increased accidents of domestic animals.	**1~2**	- Fencing for domestic animals.
N16	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	1	- Influence to cultural heritage.	**1~2**	- Adjusting of alignment.
N17	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	1	- Influence to cultural heritage.	**1~2**	- Adjusting of alignment.
N18	1	1	1	1	1~2	1~2	1	1~2	1	1	1	1	1	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height.
N19-1	1	1	1	1	1~2	1~2	1	1~2	1	1	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N19-2	1	1	1	1	1~2	1~2	1	1~2	1	1	1	1	1~2	1	1	1	- Same as above.	**1~2**	- Same as above.
N20	1	1	1	1	2	1~2	1	2	2	1	1	1	1	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Increased accidents of domestic animals. - Relocation of some houses.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals. - Adjusting of alignment.

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				5	6	7	8	9	10	11	12	13	14	15	16			
N21	1	1	1	1	2	2	1	2	1~2	1	1	1	1	1	1	1~2	- Alteration of topography. - Deforestation by excavation and embankment. - Increased accidents of domestic animals.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.
N22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N24	1	1	1	1	2	1~2	1	2	1	1	1	1	1	1	1	1~2	- Alteration of topography. - Passing near “Jabel Samhan Natural Reserve”. - Increased accidents of domestic animals.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. - Fencing for domestic animals.
N25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N27	1~2	1	1~2	1	1~2	1~2	1	2	1	1	1	1	1	1	1	1~2	- Increased traffic volume. - Alteration of topography. - Deforestation by excavation and embankment. - Increased accidents of domestic animals.	**2**	-Traffic regulation in urbanized area. - Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.
N28	1	1	1	1	1~2	1~2	1	2	1	1	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.
N29	1	1	1	1	1~2	1~2	1	1~2	1	1	1	1	1	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height.
N30	1	1	1	1	1	1~2	1	1~2	1	1	1	1	1	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height.

(7)

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				5	6	7	8	9	10	11	12	13	14	15	16			
N31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N33	1	1	1	1	1~2	1~2	1	1~2	1~2	2	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Increased accidents of domestic animals.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Fencing for domestic animals.
N34	1	1	1	1	1	1~2	1	2	1	1	1	1	1	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment.	**2**	- Minimizing excavation and embankment by adjusting alignment road height.
N36	1	1	1	1	1	1	1	2	1	12	1	1	1~2	1	1	1~2	- Deforestation by excavation and embankment. - Influence to cultural heritage. - Increased accidents of domestic animals.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. - Fencing for domestic animals.
N37	1	1	1	1	1~2	1	1	2	1	1	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N38	1	1	1	1	1~2	1	1	1~2	1	1	1	1	1~2	1	1	2	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage. - Relocation of some houses.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N40	1	1	1	1	1	1~2	1	1	1	1	1	1	1	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment.	**1~2**	- Minimizing excavation and embankment by adjusting alignment road height.
N41	1	1	1	1	1~2	1~2	1	2	1	1	1	1	1~2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				5	6	7	8	9	10	11	12	13	14	15	16			
N43	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	2	- Influence to cultural heritage. - Relocation of some houses.	**2**	- Adjusting of alignment.
N44	1	1	1	1	1~2	1	1	2	1	1	1	1	2	1	1	1	- Alteration of topography. - Deforestation by excavation and embankment. - Influence to cultural heritage.	**2**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment.
N45	1	1	1	1	1~2	1	1	2	1	1	1	1	2	1	1	1	- Same as above.	**2**	- Same as above.
N46	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	- Insignificant impact.	**1**	-
N47	1	1	1	1	1	1	1	3	1~2	1	1	1	1	1~2	1	1	- Influence to marine wildlife and mangrove vegetation. - Influence to cultural heritage. - Increased waste due to visitors.	**3**	- Minimizing excavation and embankment by adjusting alignment road height. - Adjusting of alignment. - Provision of trashcan at parking area.
B1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	- Relocation of some houses and farms.	**2**	- Adjusting of alignment.
B2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1~2	- Relocation of some houses and farms.	**1~2**	- Adjusting of alignment.
B3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1~2	- Relocation of some houses and farms.	**1~2**	- Adjusting of alignment.
B5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1~2	- Relocation of some houses and farms.	**1~2**	- Adjusting of alignment.
B6	1	1	1~2	1	1	1	1	1	1	1	1	1	1	1	1	1	- Increased traffic volume.	**1~2**	-Traffic regulation in urbanized area.
B7	1	1	1	1	1	1	1	1	1	1	1	1	1~2	1	1	2	- Influence to cultural heritage. - Relocation of some houses and farms.	**2**	- Adjusting of alignment.
B8	1	1	1~2	1	1	1	1	2	1	1	1	1	1	1	1	2	- Increased traffic volume. - Passing near the National Park. - Relocation of some houses and farms.	**2**	- Adjusting of alignment.

Project No.	Environmental Items *1 Impact Rating: 1 = Slight, 2 = Moderate, 3 = Significant																Main Factors of Impact with Project	Evaluation	Mitigation Measures
	1				**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**			
B9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-
G8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Insignificant impact.	**1**	-

*1 : Comprehensive Evaluation

1	: None to slight impacts.	: No need to carry out EIA or need to carry out partial EIA after scoping
1~2	: Small impacts.	: Recommended to carry out partial EIA on assigned items after scoping
2	: Moderate impacts.	: Recommended to carry out EIA
2~3	: Relatively significant impacts.	: Recommended to carry out EIA
3	: Significant impacts.	: Recommended to carry out EIA

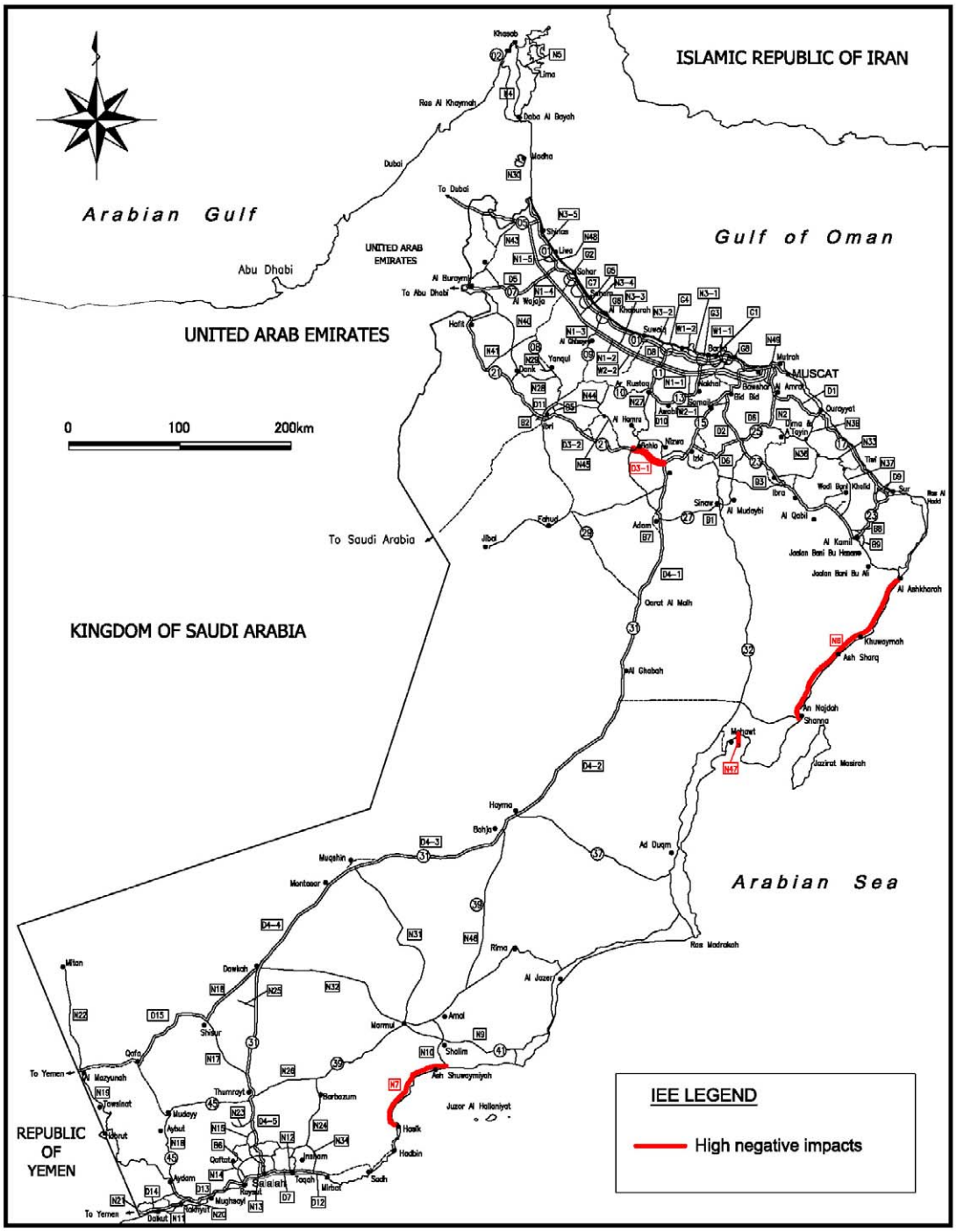


Figure 12.2-1 Project Location Map with Results of IEE

12.2.3 Results of Comprehensive Evaluation

1) Class 3

Project roads of N7 and N47 are designated as Class 3 by the comprehensive evaluation.

a. Project road N7

The project road of N7 is located between Hasik and Shuwaymiyah; the length of the project road is 80 km. No roads presently exist in the project area, and the road alignment is also not fixed yet. The coastal line between Hasik and Shuwaymiyah is locally formed narrow sand beach, and white Increase of vertical cliffs, consisting of mainly marl and limestone, mostly occupy in the project area.

The proposed road runs along the coastal line, and the project area belongs to the "Jebel Samhan Nature Reserve" area. Valuable wildlife and eco-system exist in the area.

Flora: Thick vegetation forming the dominant woodland species consisting of various species with various species of wildlife. The vegetation mainly consists of *Accacia spp., Anogeissus dhofarica (zerkin), Blepbarispermum bitum (khfut), Boscia arabica (simer), Bostvellia sacra (luban), Craton confertus (hor), Maytenus spp.,* etc. The chief species is *Anogeissus dhofarica*, which is associated with several othertrees and large shrubs such as *Commiphora* and *Acacia species*, forms the woodland vegetation.

Fauna: Wildlife in the area includes; The last population of the Arabian Leopard, Nubian ibex, Arabian Gazelle, Striped Hyenas, Wild Cats, Caracal, Wolves and Foxes. Smaller mammals including rodents and foxes (*Lupes lupes arabica*) are found in the area, along with a number of bird species. A number of rare species of birds such as Herons, Masked Boobies and Socotra Comorants are also found breeding in the area and on the cliffs. Numerous camels, cows and goats are fed in the area. However, several cows and gouts are victims by traffic accidents. Numerous kinds of birds are found in the area.

Although the protection area is mostly sheltered by steep mountainous topographic region, in case of the project road is constructed in the area, the road will not only play a role of connection between Hasik and Shuwaymiyah, but also make direct and easy access to the "Jebel Samhan Nature Reserve" area.

b. Project road N47

The project road of N47 is located at Flim and Mahawt Island; the length of proposed project road is 6 km. No roads presently exist in the project area. The road area is located shallow sand beach until island. The island is temporarily used for fishermen (400~600 families) from September to April.

Seashore of the Flim side forms wide lagoon and green mangrove. Various and valuable coastal marine wildlife exist in the area. In addition, the sea surrounding of the island forms rich fishing bank, such as barracuda, porgy, etc. The fishing bank and mangrove are so sensitive that the significant influence to the habitants around island might be anticipated to occur due to the road construction.

The proposed road needs crossing several deeply incised wadis and massive cut and embankment; therefore the construction of the road is examined significant impacts.

2) Class 2~3

Project roads of D3 and N6 are designated as Class 2~3 by the comprehensive evaluation.

a. Project road D3-1

The project road of D3 is located between Nizwa and Ibri; particularly road section D3-1 between Nizwa and Bhalah is the most sensitive zone. The length of the road section D3-1 is 36 km. The road traverses mostly flat on the Low Terrace and Alluvial wadi plains along the middle stream of Wadi Khalbuh until Tanuf. After Tanuf, the road passes low hilly terrain in the southern foot of Jabal Hajar Mountains until Bahlah. The existing 2-lane metalled road passes in the central part of Bahlah and adjoining of the Bahlah Fort (UNESCO).

The proposed 4-lane metalled road needs massive cut and embankment and the future traffic volume is predicted more than 10,000 veh/day, therefore relatively significant impacts will occur in the Nizwa and Bahlah urban areas due to the proposed road. Particularly, the road alignment should be examined in the Bahlah urban and cultural heritages zone, because central part of Bahlah is not enough space for the 4-lane metalled road alignment.

b. Project road N6

The project road of N6 is located between Al Ashkharah and Shanna; the length of

the project road is 164 km. Many aspects of this part of the coast have been identified as being particularly valuable from an ecological perspective. As such the project area has become one of the most visited areas in Oman by tourists who want to experience 'untouched' coastal and dune habitat.

Coastal set back regulations are adhered to given the sensitivity of the coastal environment, and its importance to birdlife. The road alignment within the dune system is kept at least 400 meters from the coastline to ensure beach replenishment and to avoid impacting sensitive coastal habitats.

3) Class 2

Project roads of W1, W2, D2, D4-5, D5, D11, D13, D14, N1-1~1-5, N3, N11, N12, N13, N14, N20, N21, N27, N28, N33, N34, N36, N37, N38, N41, N43, N44, N45, B1, B7 and B8 are designated as Class 2 by the comprehensive evaluation.

a. Project road W1 and W2

The project roads of W1 and W2 are located between Barka and Al Muladdah (Junction to Al Rustaq); the length of the project road is 181 km. The proposed road design is widen to 6-lane metalled road, however the road will be utilized inner area of existing ROW.

The major impact occurs only increased traffic volume. The future traffic volume in the project roads is predicted more than 40,000 veh/day; therefore significant impacts of air quality and noise might occur in the urban area, junction and roundabout. The periodical monitoring for the air quality, noise, etc. should be required.

b. Project road D2, N33, N36, N37, N38 and B8

The project roads of D2, N33, N36, N37, N38 and B8 are located in the Al Hajar Ash Sharqi Mountains. These project areas are characterized by passing in the mountainous to hilly regions. The roads pass mostly along wadis and small terraces.

Major impacts are mainly composed of alteration of topography by excavation and embankment and influence to the eco-system, flora and fauna. The project roads traverse mostly sparse vegetation, but the roads pass limited vegetation zones and farmlands with several settlements along the wadis. The vegetation in the region mainly consists of an open xenomorphic *Euphorbia* community type. Wildlife includes gazelle, red fox and small rodents. The IUCN red list of threatened animals

(IUCN 1990) describes the mountain gazelle as vulnerable. Particularly, southeastern part of the region is proclaimed as protection area of "As Saleel National Park".

The influence due to the road construction and existence of metalled roads in the region will be extended to not only deforestation of wadi vegetation, but also cut corridor of wildlife and split of habitants. Therefore, minimizing excavation and embankment by adjusting alignment road height should be strongly required.

c. Project roads of D5, D11, N27, N28, N41, N43, N44 and N45

The project roads of D5, D11, N27, N28, N41, N43, N44 and N45 are located in the Al Hajar Mountains. Crossing the mountainous region or passing the western wing of the mountains characterizes these project areas. Most of the road alignment follows along wadi.

Major impacts are mainly composed of alteration of topography by excavation and embankment and influence to the eco-system, flora and fauna. The alteration of topography by the construction of road in the mountainous region influences not only to local topographical features but also to the surface soil, ecology and landscape in the region due to massive excavation and embankment, including main road construction, borrow pits, construction camps, etc.

The project roads traverse into thick vegetation zones and farmlands with several villages where vegetation in the region is found along the entire stretch of the project area. And thick vegetation zones are mostly situated in a narrow wadi channels, showing shallow underflow or surface flow in many places. The lower lying hills have less vegetative cover than the higher areas, except for depressions and wadi flow channels. The vegetation can be classified as an open xenomorphic *Euphorbia* community type. Much of this area represents a good example of undisturbed habitat in northern Oman.

Wildlife known to the area includes the Arabian Leopard, Gazelle, Arabian tahr and other fauna such as the red fox, etc. The IUCN red list of threatened animals (IUCN 1990) describes the mountain gazelle as vulnerable. Leopard and the tahr are considered endangered.
Whilst the area does not have official reserve status, permits are required to enter some areas. Any development in the area will be considered as having a significant impact as a result of the valuable nature of the habitat.

The influence due to the road construction and existence of metalled roads in the

region will be extended to not only deforestation of wadi vegetation, but also cut corridor of wildlife and split of habitants. Therefore, minimizing excavation and embankment by adjusting alignment road height should be required.

d. Project road D13, D14, N11, N12, N13, N14, N20, N21 and N34

The project roads D13, D14, N11, N12, N13, N14, N20, N21 and N34 are located in the Salalah region of the south most of Oman. These project roads are characterized by steep slope and limestone cliff, covered by thick vegetation, connecting between salalah flat terraced lowland and flat desert highland.

Major impacts are mainly composed of alteration of slope topography by excavation and embankment and deforestation of vegetation in the region.

Flora: Thick vegetation forming the dominant woodland species consisting of various species with various species of wildlife. The vegetation mainly consists of *Accacia spp., Anogeissus dhofarica (zerkin), Blepbarispermum bitum (khfut), Boscia arabica (simer), Bostvellia sacra (luban), Craton confertus (hor), Maytenus spp.,* etc. The chief species is *Anogeissus dhofarica*, which is associated with several other trees and large shrubs such as *Commiphora* and *Acacia species*, forms the woodland vegetation.

Fauna: Wildlife in the area includes; The last population of the Arabian Leopard, Nubian ibex, Arabian Gazelle, Striped Hyenas, Wild Cats, Caracal, Wolves and Foxes. Smaller mammals including rodents and foxes (*Lupes lupes arabica*) are found in the area, along with a number of bird species. Numerous camels, cows and goats are fed in the area. However, several cows and gouts are victims by traffic accidents. Numerous kinds of birds are found in the area.

Particularly, the impacts due to the massive excavation and embankment will extend not only to the topographical features, but also to the eco-system, landscape, drainage, etc. The corridor (green belt) of wildlife will be cut and occur split of habitants. Examination of road alignment and minimizing of excavation and embankment should be required for the mitigation of impacts.

e. Project road N1-1~1-5

The project roads from N1-1 to N1-5 are located between Barka and Shinas; the length of the project road is 270 km. The road is located at inner side along the existing Batinah Highway, and the road area is mostly Low hilly and terrace plain topographic region with relatively thin to thick vegetation.

The proposed 4-lane metalled road needs massive cut and embankment, slight number of resettlement, protection of flash flood, etc. In addition, the future traffic volume is very high, predicted more than 20,000 veh/day, therefore relatively significant impacts will occur in the area.

f. Project road N3-1 ~ N3-5

The project roads from N3-1 to N3-5 are located between Bait Al Barakah and Khatmet Malahah; the length of the project road is 255 km. The road is located along the coastal line of the Al Batinah region, and the road area is mostly developed alluvial sediments, Aeolian beach sand and sand dunes. The area is covered by thick vegetation and forms continuous agricultural belt (green belt) as well as numerous villages scattered.

The proposed 4-lane metalled road needs vast land of agricultural farm, therefore many resettlements will occur. In addition, the future traffic volume is very high, predicted more than 10,000 veh/day, therefore relatively significant impacts will occur in the area.

g. Project road B1 and B7

Project roads of B1 and B7 are bypass for Sinaw and Adam Towns, respectively.

The project road of B1 is located in Sinaw; the length of the project road is 6 km. The low-lying hills in the southern part of the project area may present alignment issues and obstruction. Hence, the road alignment of the proposed bypass should be re-examined for mitigation of the impacts.

The project road of B7 is located in Adam; the length of the project road is 5 km. The proposed alignment of the bypass to the west of Adam appears to present no significant impact to the project area. Sites of historical value were identified during the surveys and these should be avoided by any construction activity.

4) Class 1~2

Project roads of D4-1 ~ D4-4, D6, D8, D9, D10, D12, N4, N5, N9-1, N9-2, N10, N15, N16, N17, N18, N19-1, N19-2, N24, N29, N30, B2, B3, B5 and B6 are designated as Class 1~2 by the comprehensive evaluation.

The slight to moderate impacts, consisting of the alteration of topography by excavation and embankment, deforestation of wadi vegetation and road alignment, are likely to effect to the environmental items, comprising of Topography and Geology, Soil, Eco-system, Flora and Fauna, Cultural Heritage and Other Impacts on Social Environment.

Alteration of topography by excavation and embankment, as well as borrow pits and construction camps, is likely to effect to the items of Topography and Geology, Soil and Eco-system, Flora and Fauna. Deforestation of wadi vegetation makes serious influence to Eco-system, Flora and Fauna and Soil. Road alignment makes influence to Cultural Heritage and Other Impacts on Social Environment.

There is not enough data and information concerning the Cultural Heritage; hence the site investigation of the cultural heritage will be required before construction. The Other Impacts on Social Environment mainly consist of traffic accidents of domestic animals and wildlife.

5) Class 1

Project roads of D4-2, D4-3, D7, D15, N22, N23, N25, N26, N31, N32, N40, N46, B9, G1 ~ G8 are designated as Class 1 by the comprehensive evaluation. The project will be inside of the ROW and no influence to the outside of the project area.

12.2.4 Tentative Mitigating Measures with Project

1) Air Pollution

Future traffic volume in 2030 is anticipated ranging from very low (less than 100 veh/day) to very high (more than 20,000 veh/day) of traffic volume. Project roads of W1-1~W1-2, D5-1~D-2, N1-1~N1-5 and N3-1~N3-5 will be predicted increase of traffic volume, more than 20,000 veh/day, particularly traffic volume of W1, W2 and N1 will be increased more than 50,000 veh/day. Hence, the air pollution by the exhaust gas from increased automobiles might occur in limited urban areas and intersections.

As to the mitigating measures for air pollution in the limited urban areas, traffic management system and enhance public transportation will be required depend on the result of monitoring of air quality. In addition, it is necessary to install systematical monitoring system for air quality in urban areas.

2) Effluent

Suspended solids (SS) caused from the roads will be improved by the installation of side ditches for discharging smoothly to the existing watercourse (wadi).

Effluent including SS, oil, grease, fuel, etc. from construction sites, asphalt plant, construction camp and quarry site should be treated before discharge to the existing watercourse, and oil, grease, etc should be collected and recycled.

3) Noise (and vibration)

Future traffic volume of project roads of W1-1, W1-2, D5-1, D5-2, N1-1 ~ N1-5 and N3-1 ~ N3-5 in 2030 is anticipated to increase more than 20,000 veh/day. The noise pollution will be caused in limited urban areas and intersection. And in case that the project road passes narrow wadi channel and settlement locates beside the road, i.e. Project road No.27; Hatta and Ar Rustaq, further traffic volume is 10,000 veh/day, noise pollution will occur.

As to the mitigating measures for noise pollution in the limited urban areas, traffic management system will be required depend on the result of monitoring of air quality. In case at the site of narrow wadi channel, it will be necessary to install soundproof to the windows faced to the road.

4) Land Subsidence

The roadbed of the project road generally consists of stable gravel or bedrocks. As no soft earth is distributed in the project area, the land subsidence will not occur.

5) Topography and Geology

Alteration of topography due to massive excavation and embankment are constructed along the existing road and proposed roads also need massive cut and embankment in many cases. The impacts will be widely extended to not only Topography and Geology, but also landscape, eco-system, fauna and flora, drainage, etc.

The mitigating measures of alteration of the topography should be examined realignment and alternatives including bridge and tunnel, etc.

6) Soil

Soil is scarcely developed in the project area, and soil erosion is caused by drainage

water and wind. Most of soil is eroded and transferred from origin to downstream of wadis and formed wadi sediments as alluvial deposits.

Particularly, soil erosion by rainwater will be mitigated due to installation of drainage system.

7) Hydrology and Groundwater

Existing national roads are installed culverts and drainpipes along the wadis. The slopes are also installed side ditches. It is necessary to density installation of drainage system in case of the project roads.

Flash flood will occur in many wadis around the Oman Mountains and Salalah area. Particularly, the areas of Dank to Ibri, Quriyat, Sur and Salalah have Increase of potential to occur flash floods, and road damages due to flash flood had occurred in many places. Bridges and box culverts should be constructed instead of Irish crossing in order to mitigate impact by the flash flood.

8) Ecosystem, Flora and Fauna

Thick vegetation and valuable wildlife are found in the Oman Mountains, Batinah Region, Salalah area and near coastal line of the central part of Oman. Particularly, the slopes, facing to the south, in Salalah area are covered by rich vegetation living with wildlife as well as grazing domestic animals.

Road construction traversing into the thick vegetation area should be avoided for the conservation of eco-systems. Hence, it is necessary to minimize right-of-way and affecting area.

The project roads, adjoined to the protection area, should be considered to set buffer zone, notice board, fence, etc. in order to avoid damage from poaching, etc.

9) Landscape

Landscapes depend on the Topography and Geology, vegetation, water, natural heritage, etc. Massive cut and embankment, felling of forest, etc. should be avoid or minimize in road construction.

10) Regional Development on the Natural Environment

Road planning is necessary to examine on the regional developments in the project

area for the mitigation of the impacts to the natural environment.

11) Hazards

Hazards related to the project roads mainly consist of traffic accident by domestic animals and rainfall, flash flood along wadis, traffic interruption by sand storm and sand dune, slope failure, etc. The establishment of monitoring system for various hazards will be required.

12) Wastes

Litter boxes are installed each parking area and bus stop along the major roads. The Directorate General of Roads (MT&C) has a function to manage of cleaning of the national roads, and major roads relatively keep being clean.

13) Cultural Heritage

Prior road construction, the Ministry of Heritage and Culture will carry out site investigation for the cultural heritage. In case of encountered heritages, road alignment should be amended to avoid the land of heritage.

14) Regional Development on the Social Environment

Road planning is necessary to examine on the regional developments in the project area for the mitigation of the impacts to the social environment.

On the resettlement by road alignment, resettlement by road alignment of resident for the road construction should be minimized or avoided due to change of road alignment.

12.3 RECOMMENDATIONS

1) Project road N7

The project road of N7 is Increase of negative impacts to the topography/geology, eco-system, flora and fauna, landscape, etc. The proposed road runs along the coastal line, and the project area belongs to the “Jebel Samhan Nature Reserve” area. Valuable wildlife and eco-system exist in the area.

The protection area is mostly sheltered by steep mountainous topographic region. In case of the project road is constructed in the area, the road will not only play a role

of connection between Hasik and Shuwaymiyah, but also make an access road directly and easily to the “Jebel Samhan Nature Reserve” area.

It is necessary to re-examine alternatives and countermeasures for the mitigation of the impacts due to the road construction. The implementation of comprehensive EIA, including marine wildlife investigation, is strongly recommended.

2) Project road N47

The project road of N47 is Increase of negative impacts to the eco-system, flora and fauna, topography/geology, and landscape. The eco-system mainly consists of wide lagoon, scattered mangrove, fishing bank and sea current, etc. Particularly, sea current around the Mahawt Island will be sensitively impact due to the road construction.

The mitigation of the impacts due to the road or bridge is extremely difficult. Therefore, alternatives, including abandon of the road project, should be re-examined. The implementation of comprehensive EIA, including sea current investigation, is strongly recommended.

3) Project road D3-1

Project road of D3-1 is designated as Class 2~3 by the comprehensive evaluation.

Therefore, the mitigation of the impacts and alternatives due to the road construction should be re-examined. The implementation of comprehensive EIA, including detail investigations, is strongly recommended.

4) Project road N6

Project road of N6 is designated as Class 2~3 by the comprehensive evaluation.

Therefore, the mitigation of the impacts and alternatives due to the road construction should be re-examined. The implementation of comprehensive EIA, including detail investigations, is strongly recommended.

6) Project roads of D4-1 ~ D4-4, D6, D8, D9, D10, D12, N4, N5, N9-1, N9-2, N10, N15, N16, N17, N18, N19-1, N19-2, N24, N29, N30, B2, B3, B5 and B6 are designated as Class 1~2 by the comprehensive evaluation.

Project roads of W1-1, W1-2, W2-1, W2-2, D2, D3-2, D6, D8, D9, D10, D11, D12, N9, N10, N12, N15, N18, N19, N22, N24, N27, N28, N29, N38, N41, N43, B2 and B5 are designated as Class 2 by the comprehensive evaluation.

Therefore, the mitigation of the impacts due to the road construction should be examined. The implementation of comprehensive EIA is recommended.

7) Project roads of D4-1 ~ D4-4, D7, D15, N2, N16, N17, N23, N25, N26, N30, N31, N32, N40, N46, B3, B4, B6 and B9

Project roads of D4-1 ~ D4-4, D7, D15, N2, N16, N17, N23, N25, N26, N30, N31, N32, N40, N46, B3, B4, B6 and B9 are designated as Class 1~2 by the comprehensive evaluation.

Therefore, the mitigation of the impacts due to the road construction should be examined. The implementation of comprehensive EIA or partial EIA on assigned environmental items after scoping is recommended.

8) Project roads of D4-2, D4-3, D7, D15, N22, N23, N25, N26, N31, N32, N40, N46, B9, G1 ~ G8

Project roads of D4-2, D4-3, D7, D15, N22, N23, N25, N26, N31, N32, N40, N46, B9, G1 ~ G8 are designated as Class 1 by the comprehensive evaluation. The project will be inside of the ROW and no influence to the outside of the project area.

Therefore, none of EIA or partial EIA after scoping is recommended.

CHAPTER 13

ROAD MAINTENANCE AND MANAGEMENT PLAN

CHAPTER 13

ROAD MAINTENANCE AND MANAGEMENT PLAN

13.1 REVIEW OF CURRENT PRACTICE OF MAINTENANCE

13.1.1 Type of Maintenance Works

Maintenance works are usually categorized into the following three types:

- Routine maintenance
- Periodical maintenance
- Other maintenance

Table 13.1-1 presents examples of typical work items of these types of maintenance.

Table 13.1-1 Examples of Typical Work Items for Maintenance Types

Type of Maintenance	Examples of Typical Work Items
Routine Maintenance	- Cleaning of road surface, side ditches, culverts etc - Trimming and cutting of trees and grasses - Checking and replacing defective parts of road lamps, traffic signs, guard rails etc.
Periodical Maintenance	- Overlay and rehabilitation of pavement - Replacement of expansion joints, bearing shoes etc. of bridges - Repainting of steel bridges
Other Maintenance	- Repair of parts of road damaged by natural disaster - Repair of defects of bridges other than those done in Periodical Maintenance

13.1.2 Length of Roads Maintained

Table 13.1-2 shows the total lengths of paved roads and track roads maintained by DGR in each region. DGR is currently maintaining 5,170 km of paved roads and 12,375 km of track (unpaved) roads. Table 13.1-3 shows the total lengths of paved roads and track roads maintained by DGC.

Table 13.1-2 Total Length of Roads and Contract Amounts of Maintenance

Region	Paved Road			Track Road		
	Total Length (km)	Contract Amount (RO 1,000)	Ave. Unit Price (RO /km/yr)	Total Length (km)	Contract Amount (RO 1,000)	Ave. Unit Price (RO /km/yr)
Musandam	115	540	1,174	449	851	473
Al Batinah	1,198	1,596	333	3,586	2,767	193
A'Dhahira	638	1,756	688	2,658	1,517	143
A'Dakhliyah	1,186	1,840	388	2,796	1,862	166
A' Sharqiyah	933	1,756	470	2,855	2,120 (Include those of Al Wusta)	186
Al Wusta	1,100	2,382	541	31 (Included in Ash Sharqiyah)	(Included in Ash Sharqiyah)	N.A.
Total	5,170	9,870	477	12,375	9,117	184
Total Contract Amount			RO 18.987 million (4 years)			
Per Year			RO 4.747 million			

Note: Contract Period 2002-2005

Table 13.1-3 Lengths of Roads Maintained by DGC (km)

Paved Road		Track Road	
Total Length (km)	Contract Amount (RO 1,000)	Total Length (km)	Contract Amount (RO 1,000)
1375	2,471	2,581	5,540

13.1.3 Out-sourcing of Maintenance Works

DGR and DGC have already adopted out-sourcing (privatization) of maintenance works. Actual maintenance works are undertaken by private firms (contractors) while DGR and DGC supervise the works done by the contractors. The work items included in the contract of maintenance are routine maintenance and some small-scale emergent repair works for damages caused by traffic accidents or by rain and wadi floods as described in Subsection 4.2.2.

Table 13.1-2 shows contract amounts of maintenance works. Wide variation is seen both in unit cost for paved roads and track roads among regions. This may be due to large difference of conditions such as terrain and distance from the bases of labor, material and equipment. On nationwide average basis, unit costs of maintenance are RO 477 and RO 184 for paved roads and track roads, respectively. Average annual maintenance cost for DGR is approximately RO 4.75 million.

In many countries, maintenance cost of paved road is smaller than that of unpaved road due to frequent grading of unpaved surface. In case of the Sultanate, higher maintenance cost of paved roads is attributed to higher level of maintenance applied for paved roads. While the main work of maintenance of track roads is grading of the surface, the maintenance works of paved roads include various items including cleaning of side ditches and culverts, small repair of pavement and other facilities of roads, and replacement of damaged guard rail, which are not included in the work items of maintenance of track roads.

Another unique feature of practice of road maintenance of Oman is relatively long contract period (4 years). This contract system gives both advantages and disadvantages as follows:

Advantages

- Workload of DGR officials for tendering-bidding-contracting is greatly reduced compared with the shorter contract period.
- Contractors are assured for jobs for relatively long period and can make plan for stable supply of labor, material and equipment, resulting in reduced costs.

Disadvantage

- Once a contractor is awarded a contract, usually the contract is assumed to continue for 4 years. Thus, contractor tends to be satisfied with minimum level of work quality.

Considering these advantages and disadvantage, the preset system is judged to be appropriate unless some new problems become apparent in the future.

13.2 FUTURE MAINTENANCE DEMAND

13.2.1 Total Length of Paved Roads to be Maintained

The lengths of DGR roads and DGC roads by surface and road type at present and in the future are summarized in Table 13.2-1 and graphically shown in Figure 13.2-1. Figure 13.2-1 compares the total lengths of paved primary and secondary road in year 2003 and 2030 both in simple lengths and the length converted to “Single-Carriageway-Equivalent Length” (the length of double carriageway (4-lane) roads multiplied by 2 to equalize with single carriageway roads with regard to the work load of maintenance).

Table 13.2-1 Length of Roads by Surface and Road Type (Unit: km)

Pavement/Road Type	As of 2003			Increase in 04-05	Increase with M/P	As of 2030
	DGR	DGC	Total			
Paved, Double Carriageway (1)	461	70	531	114	1,959	2,604
Single-Carriageway-Equivalent Length [(1) x 2] (2)	922	140	1,062	228	3,972*	5,262
Paved, Single Carriageway (3)	4,709	1,346	6,055	1,138**	2,909**	8,493
Subtotal for Paved Road (Single and Dual) [(1) + (3)]	5,170	1,416	6,586	1,252	4,865	11,097
Subtotal of Paved Road (in Single-Carriageway-Equivalent-Length) [(2) + (3)]	5,631	1,486	7,117	1,366	6,878	13,755
Local & Access Road[1] (Out of M/P)						
Paved Road*** (4)	0	2,218	14,593	-	5,000***	5,000***
Unpaved Road***	12,375			-	(-7,500)	(7,093)
Total Length of Paved Road [(1) + (3) + (4)]	5,170	1,416		-		16,097
Total Length of Paved Road in Single-Carriageway-Equivalent Length [Total of (2) + (3) + (4)]	5,631	1,416	7,117	-	-	18,755

* Section of widening for 6 lanes are multiplied by 3.

** Length of dualized section (new construction of expressway & bypasses not included) is subtracted.

*** It is expected that track roads will be constructed during Master Plan Period. However, for the purpose of Maintenance Plan, it is assumed that the existing track roads will be paved and no new track roads will be constructed. Further, an average annual growth rate of total length of paved road is assumed to be 500 km/yr. Out of total 12,500 km of growth of length of paved roads for the period 2006-2030, about 5,000 km is scheduled in the Master Plan. The remaining 7,500 km is assumed to be attained by paving of local and access roads.

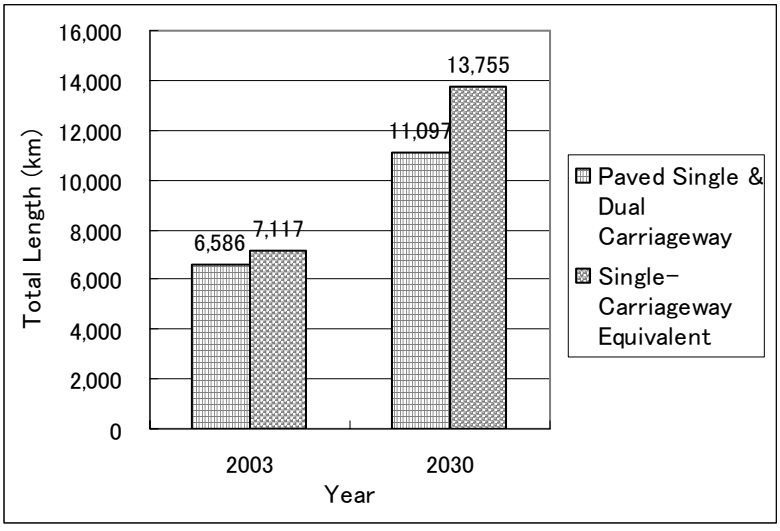


Figure 13.2-1 Future Increase of Paved Road Length

[1] Local and access roads are out of scope of this Study. However, workload of maintenance of these roads needs to be taken into account in preparing maintenance plan.

Figure 13.2-2 shows the total length of paved roads including Primary, Secondary, Access and Local Roads in "Single-Carriageway-Equivalent Length". As it is seen in the table and figure, total lengths of paved roads to be maintained by DGR and DGC in year 2030 will increase to about 3 times of that in year 2003, mainly due to increase in paved local and access roads. Routine maintenance with higher cost than that of track roads will be necessary for the extended paved road network.

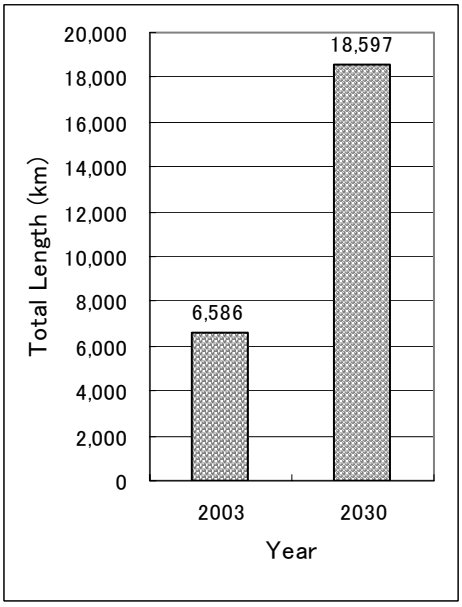


Figure 13.2-2 Total Length of Paved Roads Including Access & Local Roads

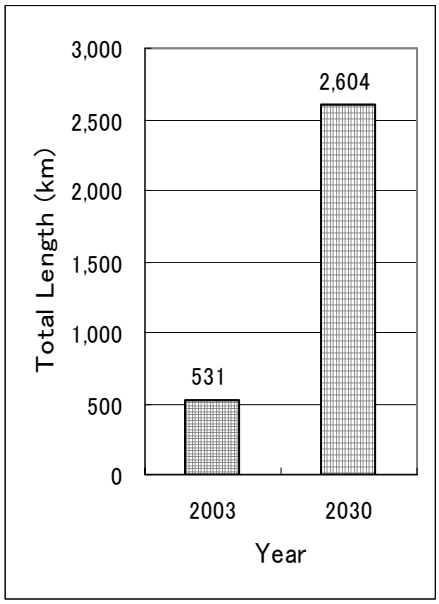


Figure 13.2-3 Increase in Length of Dual Carriageway Roads

Figure 13.2-3 shows increase of total length of dual carriageway roads. Maintenance of dual carriageway roads requires higher level of works because of its higher travel speed of vehicles than that of single carriageway roads. This increase in total length of dual carriageway roads will result in increase in workload of maintenance.

13.2.2 Rehabilitation of Pavement

When the total length of paved roads grows, the cost of periodic maintenance (overlay/ rehabilitation) of pavement often imposes considerable financial burden to the government.

1) Life Period of Pavement in Oman

"Road Inventory Update", DGR, 1993 lists the years of construction of roads. Ages of

existing pavement can be calculated from this Road Inventory Update. Table 13.2-2 shows the ages of pavements which were completed before 1990 and present condition of these pavements rated through the Road Inventory Survey of this Study. As it is seen in the table, many pavements which are 25 years old or older are still in good or fair condition, meaning no urgent rehabilitation is necessary. According to DGR, no overlay has been executed on these pavements except for Batinah Highway (NR 01). For other road sections with "Bad" pavement condition, such as Bid Bid-Sur Road (NR 23) and Adam-Thumrayt Road (NR 31), rehabilitation is currently being implemented. Therefore, it is assumed that the average life period of pavement is 25 years.

Table 13.2-2 Age and Condition of Pavement (Constructed Before 1990)*

Road No.	Road Name (Section)	Year of Opening	Age (Years)	Present Condition**	Remarks
01	Batinah Highway	1973-74	30-31	F-G (Part. B)	Heavy traffic Patching done
05	Wadi Hatta Road	1978 (81)	26 (23)	G	
07	Sohar-Buraymi Road	1977	27	G (Part. F)	
09	Al Khaburah-Ibri Rd (Ibri-Daiz Sec)	1979	25	F	
11	Muladdah-Rustaq Rd	1976	28	G	
13	Barka-Rustaq Rd	1982	22	G	
15	Rusayl-Nizwa Rd	1975	29	F-G	Dualized in 2002
21	Ibri-Buraymi Nizwa-Ibri	1976 1978-80	28 24-26	G F-G	
23	Bid Bid-Sur Rd	1977	27	F-B (Part. G)	
27	Sinaw-Mudaibi-Haimah	1987-88	16-17	G	
28	Lisq-Ibra	1988	16	G	
29	Ibri-Tanam	1976	28	F	
31	Firq-Adam-Thumrayt Thumrayt-Alalah	1980-82 1976	22-24 28	B-F-G G	Unfavorable subgrade suspected
47	Salalah-Raysut Raysut-Mughsayl Mughsayl-Furious	1973 1082 1989	31 22 15	F F F	

* Local roads and roads in Muscat Governorate are not included.
** G: Good F: Fair B: Bad
Data source for year of construction of pavement: Highway Inventory Data, DGR, 1993

2) Ages of Existing Pavement

Figure 13.2-4 shows the total lengths of pavement constructed in the past 5-Year Plans. Majority of pavement were constructed after 1980, meaning that they are less than 25 years old. However, 2,107 km of pavement was constructed in 1980 or before. If pavements need rehabilitation 25 years after their construction, these old pavements will need rehabilitation in the period of next 7th 5-year Development Plan. This will require considerable cost and effort of DGR staff.

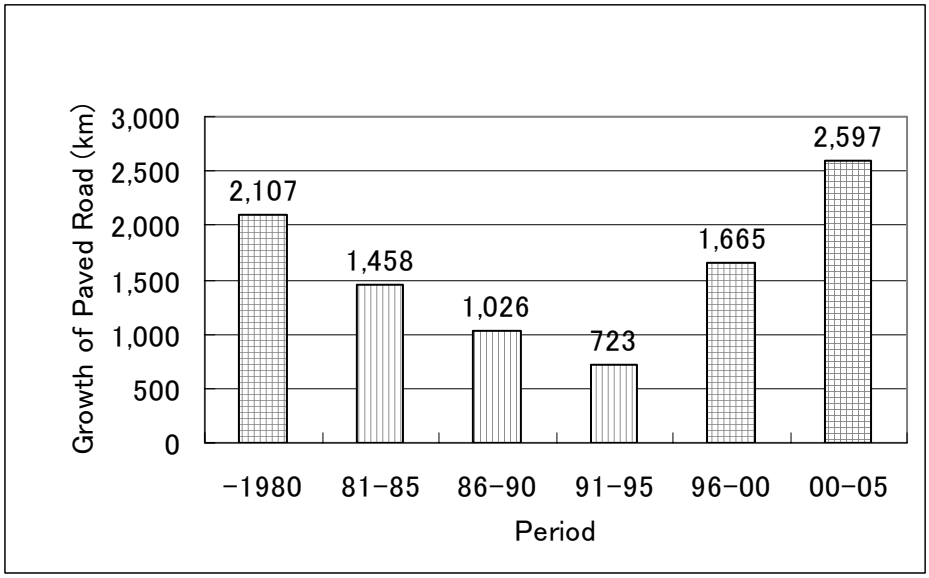


Figure 13.2-4 Total Lengths of Pavement Constructed in Past 5-Year Plan Periods

13.3 PROBLEMS OF FUTURE MAINTENANCE

Since maintenance works are contracted out and contractors have satisfactory capacities for accomplishing their tasks, there will be little problems in actual implementation of execution works in the future. Relatively few problems are anticipated with regard to future road maintenance on the side of DGR and DGC except the following two major problems:

(i) Financial burden
(ii) Insufficient institutional capacity of DGR

The problem of financial burden is discussed in the following subsection while the problem of insufficient institutional capacity is discussed in Section 13.6 “Organizational Plan”.

13.4 MAINTENANCE PLANNING

Planning of road maintenance aims at preparing the schedule of necessary works, including pavement rehabilitation, and estimation of required fund to implement the scheduled works. In this section, mainly routine maintenance and periodical maintenance and their required budgets are discussed. Other types of maintenance, such as repair of damages caused by flash floods, are not discussed since they are difficult to forecast. It is practical to plan the repair works after such damage happened.

13.4.1 Routine Maintenance

1) Growth of Road Length in Future

Table 13.4-1 and Figure 13.4-1 show the growths of total length of paved roads, converted into Single- Carriageway-Equivalent Length (SCEL) in 7th to 11th 5-Year Development Plan periods.

Table 13.4-1 Growth of Paved Road Length (SCEL) (Unit: km)

5-Yerar Plan Period	2005	7th (2006-10)	8th (2011-15)	9th (2016-20)	10th (2021-25)	11th (2026-30)
Increase (M/P)	0	1,025	891	1687	676	1,101
Total Length at the End of Period	8,483	9,508	10,399	11,895	12,762	13,755
Increase of Local & Access Road	0	1,000	1,000	1,000	1,000	1,000
Total of All Paved Roads	8,483	10,008	11,399	12,395	13,762	18,755

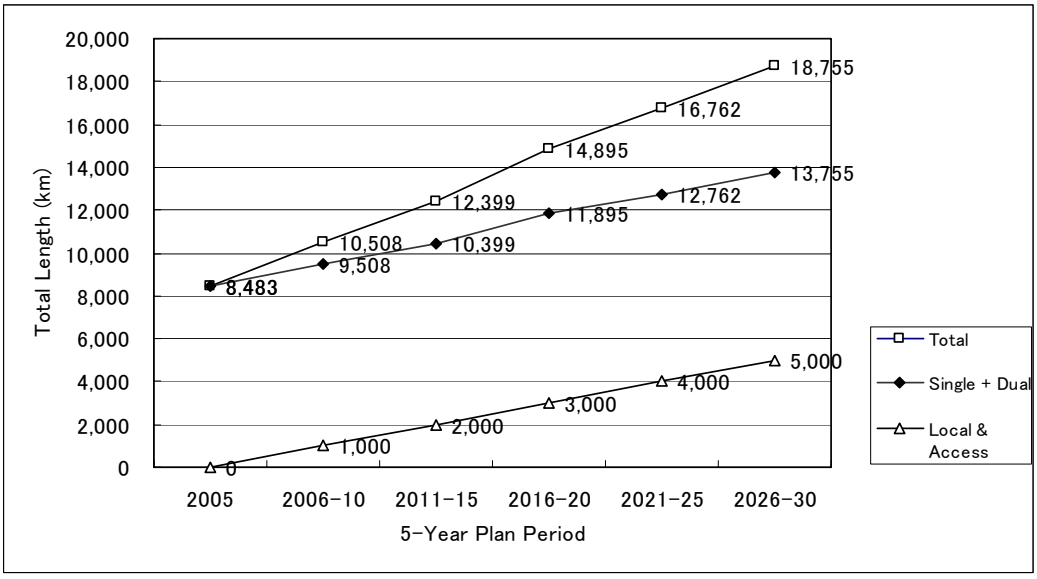


Figure 13.4-1 Growth of Paved Road Length (in SCEL)

2) Cost for Routine Maintenance

To estimate the cost of routine maintenance, the total length of roads to be maintained in each 5-Year Plan period is calculated by averaging the length at the beginning and end of each period. Table 13.4-2 shows the average road length used in the cost estimation of routine maintenance.

Table 13.4-2 Calculation of Average Road Length (SCEL: km)

5-Year Plan Period	7th (2006-10)	8th (2011-15)	9th (2016-20)	10th (2021-25)	11th (2026-30)
Length at Beginning of Period	8,483	9,508	10,399	11,895	12,762
Length at End of Period	9,508	10,399	11,895	12,762	13,755
Average Length	8,996	9,954	11,147	12,329	13,259

Table 13.4-3 and Figure 13.4-2 show the cost of routine maintenance estimated using the average unit costs shown in Table 13.1-2. The cost of routine maintenance of the Master Plan for the 7th 5-Year Period is about RO 23 million. It increases to RO 34 million in 11th 5-Year Period.

Current unit costs of maintenance for paved and track road are RO 477/km/year and RO 184/km/year, respectively, as presented in Table 13.1-2. Considering the possible price escalation, and based on the discussions with DGR, the above unit costs are increased to RO 510/km/year and RO 220/km/year, respectively, to be used in the Master Plan (See Table 13.4-3).

Table 13.4-3 and Figure 13.4-2 show also the maintenance cost of local and access roads which are not included in the Master Plan. It should be noted that the total of routine maintenance costs for these roads amounts to about 70% (in 7th 5-Year Period) to about 50 % (in 11th 5-Year Period). Therefore, sufficient consideration should be given to secure these maintenance costs.

The Total of routine maintenance costs for the Master Plan and local & access roads for 5-Year Periods are about RO 40 million in 7th 5-Year Development Plan and increases to about RO 53 million in 11th 5-Year Development Plan.

Table 13.4-3 Cost for Routine Maintenance

5-Year Period	7th (‘06-‘10)	8th (‘11-‘15)	9th (‘16-‘20)	10th (‘21-‘25)	11th (‘26-‘30)	
Master Plan Roads						
Average Maintenance Length*(SCEL: km)	8,996	9,954	11,147	12,329	13,259	
Unit Cost (RO/km/yr)	510	510	510	510	510	
Maintenance Cost (Per Year) (RO million)	4.588	5.076	5.685	6.288	6.762	MP Total
(Per 5-Year Period) (RO million)	22.94	25.38	28.42	31.44	33.81	141.99
Local & Access Roads (Out of Master Plan)						
Ave. Maintenance Length (Paved Road) (km)	500	1,500	2,500	3,500	4,500	
Unit Cost (RO/km/yr)	510	510	510	510	510	
Maintenance Cost (Per Year) (RO million)	0.255	0.765	1.275	1.785	2.295	
Ave. Maintenance Length (Track Road) (km)	13,593	11,593	9,593	7,593	5,593	
Unit Cost (RO/km/yr)	220	220	220	220	220	
Maintenance Cost (Per Year) (RO million)	3.100	2.770	2.330	1.890	1.450	
Subtotal for Access & Local	3.355	3.535	3.605	3.675	3.745	Total
Maint. Cost for Local & Access Road per 5-Year	16.78	17.68	18.03	18.38	18.73	89.60
Grand Total	39.72	43.06	46.45	49.81	52.54	231.59

* Average of road length at the beginning and end of the Plan

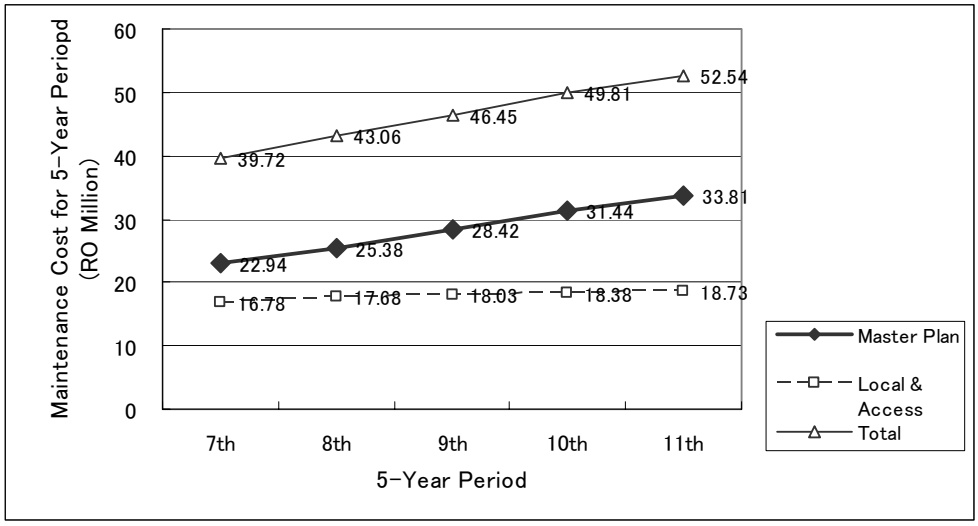


Figure 13.4-2 Cost of Routine Maintenance for Each 5-Year Plan Period

13.4.2 Periodic Maintenance

1) Main Work Item of Periodic Maintenance

Periodic maintenance includes such works as pavement overlay, pavement rehabilitation, replacement of expansion joint and bearing shoe of bridge and repainting of steel bridges. In case of the Sultanate, the number of bridges is still very limited and cost and workload for these maintenance works are very small compared with those of overlay/rehabilitation of pavement to the extent that they can be disregarded in the Master Plan. (However, this does not mean that these maintenance works can be ignored, of course.)

As for periodic maintenance of pavement, almost all the textbooks of pavement emphasize the importance of sealing of cracks and overlay at appropriate timing to prevent premature failure and minimize the overall maintenance cost of pavement. However, in case of the Sultanate, actual life periods of pavement are very long compared with those in other countries, even without overlay. This situation is illustrated in Subsection 13.2.2. The long life of pavements in the Sultanate may be attributed to the following facts:

- **Light traffic**: In the past and at present, traffic volumes on majority of roads in the Sultanate, with few exceptions such as Batinah Highway and Bid Bid-Sur Road (NR 23), are small. In addition, percentage of heavy vehicles in the traffic is also usually small.
- **Favorable subgrade condition**: In many cases, materials of subgrade are granular (gravel or sand). These types of materials usually have high bearing capacity. Accordingly, the strength of entire pavement (including subgrade) is very high.
- **Scarce rainfall**: In many other countries, rainwater is a major cause of premature failure of pavement. Once cracks start to develop in the pavement, rain water infiltrate to base course, subbase course and subgrade and lessens the bearing capacities of these materials, leading to rapid progress of development of cracks. In case of the Sultanate, rainfall is very scarce. In addition, the material of the subgrade is usually granular and does not weaken very much with little infiltration of rainwater.

As revealed through the Road Inventory Survey, pavements with noticeable cracks can support heavy vehicles and vehicles can travel at high speed such as 120 km/hr.

For these reasons, it is considered that rehabilitation (reconstruction) at the time of substantial development of cracks and before development of potholes, as currently

practiced, is the most practical way of periodical maintenance of pavement in the Sultanate. Accordingly, this method is adopted and incorporated as the main work item of the periodic maintenance in the Master Plan.

2) Future Demand of Pavement Rehabilitation

Based on the length of pavement constructed each 5-Year Periods in the past, as presented in Figure 13.2-1, the future demand of pavement rehabilitation is estimated. The following assumptions are adopted in the process of estimation:

- Basic life period of pavement is 25 years.
- Although the pavements to be rehabilitated in 7th 5-Year Development Plan (2006-2010) (constructed in 1980 or before) are aged more than 25 years, one quarter (1/4) of the total length to be rehabilitated in this period do not need rehabilitation during 7th period and the rehabilitation can be carried forward to 8th period. This assumed that many of these pavements are rated as "Good" in the Inventory Survey.
- Similarly, one quarter of the total length for 8th (2011-2015) period is carried forward to 9th period considering that the increase of traffic volume of heavy vehicles is still moderate.
- As for the pavements to be rehabilitated in 9th (2016-2020) and 10th (2021-2026) period, the life of all the pavement becomes 25 years due to increase in traffic volume of heavy vehicles.
- As for one quarter (1/4) of the pavements to be rehabilitated in 11th (2021-2025) and 12th (2031-2035; not included in Master Plan) period, the life is shortened to 20 years due to further increase in heavy vehicles, and this length is advanced to the preceding periods (10th and 11th, respectively).

Table 13.4-4 shows the process and the result of estimation of future demand of pavement rehabilitation. Figure 13.4-3 graphically shows the future demand of pavement rehabilitation.

Table 13.4-4 Estimation of Future Demand of Pavement Rehabilitation (km)

5-Year Plan Period	7th	8th	9th	10th	11th	12th
Basic Length for Rehabili.	1,877*	1,458	1,026	723	1,665	2,597
Carried Over to Next Period	469.3	364.5	0	0	0	0
Carried Over from Preceding Period	0	469.3	364.5	0	0	0
Advanced to Preceding Period	0	0	0	0	416.3	649.3
Advanced from Next Period	0	0	0	416.3	649.3	-
Total Length of Rhabili.	1,408	1,563	1,391	1,139	1,898	-

* Among 2,107 km constructed before 1980, 230 km have been rehabilitated in 6th Plan period.

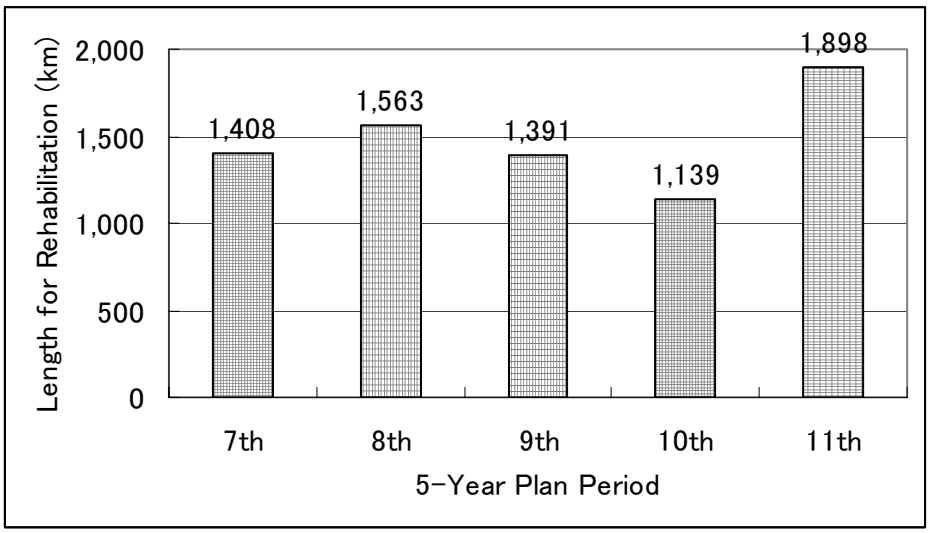


Figure 13.4-3 Future Demand of Pavement Rehabilitation

3) Cost of Pavement Rehabilitation

Unit Cost

Unit costs of pavement rehabilitation are estimated in Section 11.3 and presented in Table 13.4-5 below:

Table 13.4-5 Unit Cost of Pavement Rehabilitation (2 Lane) (RO 1,000/km)

Terrain	Flat	Rolling	Mountainous
Unit Cost	33	39	43

The result of Road Inventory Survey showed the shares of terrain types over the existing road network as presented in Table 13.4-6. (See Subsection 4.4.2)

Table 13.4-6 Share of Terrain Type

Terrain	Flat	Rolling	Mountainous	Total
Share (%)	84	6	10	100

Based on these shares, average unit cost of pavement rehabilitation is calculated as follows:

Average Unit Cost = [(33 x 84) + (39 x 6) + (43 x 10)]/100 = 34.36 (RO 1,000)

This unit cost, however, is considered to be low according to DGR. Therefore, RO 50,000/km/year is adopted as the unit cost. Costs of pavement rehabilitation for each

5-Year Plan period is obtained by multiplying the above average unit cost by the length to be rehabilitated in the period. Table 13.4-7 and Figure 13.4-4 show cost of pavement rehabilitation for each 5-Year Plan period.

Table 13.4-7 Cost of Pavement Rehabilitation for Each 5-Year Plan Period

5-Year Plan Period	7th	8th	9th	10th	11th	Total
Length of Rehabilitation	1,408	1,563	1,391	1,139	1,898	7,398
Unit Cost (RO/km)	50,000	50,000	50,000	50,000	50,000	-
Total Cost (RO million)	70.39	78.14	69.53	56.96	94.90	369.92

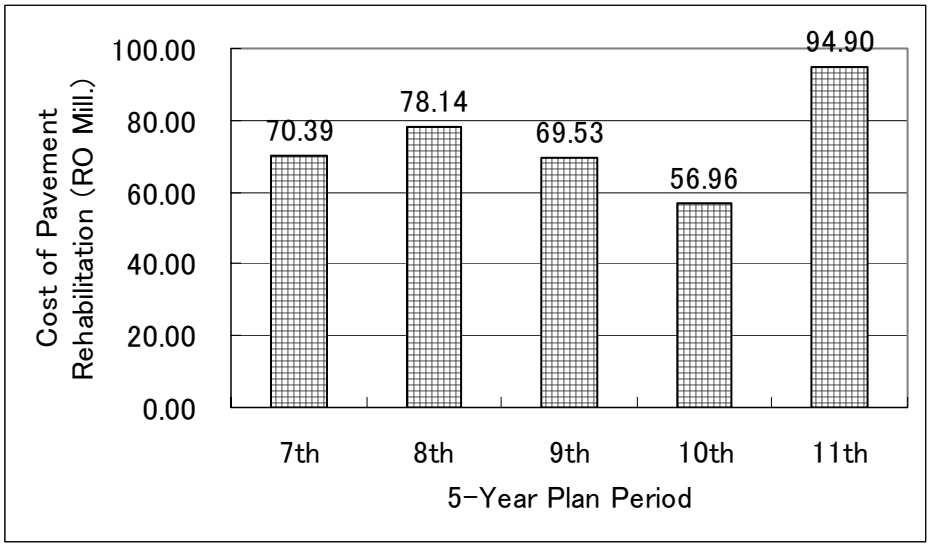


Figure 13.4-4 Cost of Pavement Rehabilitation for Each 5-Year Plan Period

4) Identification of Sections to be Rehabilitated

Among paved sections with a total length of 5,925 km surveyed under the Road Inventory Survey, 5.5 % equivalent to 326 km are rated as “Bad” and 1.5 % or about 90 km are rated as “Very Bad”. (Sections rated as Bad and Very Bad are listed in Appendix 4-2.) Pavements of some of these sections are being rehabilitated or being planned to be rehabilitated in the near future. The remaining sections need to be rehabilitated as soon as possible, or in 7th 5-Year Plan Period (2006-2010), at latest.

Other sections to be rehabilitated in 7th 5-Year Plan Period should be identified based on the results of pavement condition survey. The pavement condition survey should focus on the sections with “Fair” rating as indicated in Appendix 4-2, particularly those aged more than 20 years.

Pavement condition survey should be conducted preferably every year. The sections to be rehabilitated in the following year (or in the same year if urgent) should be identified and the rehabilitation plan for the following year should be prepared.

Further, life period of pavement may become shorter than that of present due to the increase in traffic volume, especially that of heavy vehicles. Traffic volume is one of the governing factors of pavement life period.

Pavement condition survey require substantial field work of engineers since it needs visual observation of pavement conditions. For this reason, it is proposed that the capacities of Regional Road Departments be strengthened as described in Section 13.7.

13.5 TRAFFIC MANAGEMENT AND ROAD USERS SERVICES

Traffic management[2] is very important for efficient usage of road facilities. Even if a road is physically in a good condition, there may be confusion in traffic if proper traffic management is not applied. In the past, road administration of the Sultanate has been mainly concentrated on physical improvement of road facilities. Now that the physical road facilities have been substantially improved, attention should be directed towards better usage of road facilities through proper implementation of traffic management measures.

The major part of "traffic administration" is "traffic control". Royal Oman Police (ROP) is the principal line agency for traffic control. Present traffic control by ROP includes the following:

- Installation and operation of traffic lights and traffic signs
- Designation and enforcement of speed limits
- Regulation and enforcement of parking
- Regulation of travel of heavy vehicles
- Closure of road due to traffic accident, hazardous road and weather conditions including flood in wadi.

In many countries including Japan, traffic control centers are established and operated

2 Similar terminologies as "traffic control", "traffic management", "traffic administration" and "traffic operation" are used. In this report, the word "traffic control" is used to mean regulation and enforcement of vehicle speeds, parking, manner of driving vehicle or vehicle travel and other similar subjects which are implemented by police departments in many countries while the "traffic administration" is used to mean actions done to secure safe and smooth traffic. Thus "traffic administration" as used in this report covers wider spectrum of actions than, and including, "traffic control".

jointly by police department and road administrator to provide better traffic control utilizing data/information of traffic volume, weather traffic condition including accident and congestion etc. Figure 13.5-1 shows an example of traffic control center jointly operated by police department and road administrator.

Figure 13.5-1 Example of Traffic Control Center

Other types of traffic management actions are usually intended to improve convenience of drivers and passengers, and, thus, often called “road user services”. They are implemented mainly by road administrator or planned by road administrator and implemented by a third party including private enterprises. Road user services are important and effective for increasing usage of roads or travels on roads. Therefore, road user services are important for future development of road traffic.

13.5.1 Road User Services

Providing good driving environment is indispensable for safe and comfortable travel. The types of services which should be available to the road users include the following:

(i) Services of supplying fuel
(ii) Services of repair shop
(iii) Services of restaurant
(iv) Road-side repair or towing services to repair shop for broken-down vehicles
(v) Medical services (for those involved in accident or unexpected illness)
(vi) Information on road (cities and towns on the route, road number, etc.)
(vii) Information on traffic condition and weather (traffic congestion, accident, road works, hazardous weather conditions such as heavy rain, strong wind and flood, etc.)

1) Supply of Fuel, Repair Shop, Restaurant and Towing Service

Items (i) to (iv) are needed for daily use of roads. In the Sultanate, in case of relatively large cities or along heavily trafficked road, gasoline stations located at sufficient intervals and the services of repair shop and restaurant or food stuff are often provided. On the other hand, these services are difficult to find on the roads with low traffic volume. Awareness of the road users that such services are available at certain intervals gives the road users a sense of "secured" and encourage them to travel long distance. Therefore, the Government should encourage opening of such shops. On some important road with small traffic volume, such as NR 31 in Al Wusta Region, it may be necessary that the government subsidize the providers of such services for the benefit of road users**.**

2) Information on Roads

For those drivers who are not familiar with the road maps of the area, one of the most useful information is road number (NR 01, etc.). Currently, there are "Confirmatory Signs" showing the name of cities ahead of the road with road number. However, intervals of such signs are not close enough. One of the measures for the insufficiency of such signs is to install clear and easy-to-recognize signs of road numbers along the road at closer intervals and after major junctions. Signs of road numbers are particularly helpful for tourists and drivers from neighboring countries. Figure 13.5-2 shows an example of rod number sign.

Figure 13.5-2 Road Number Sign

3) Information on Traffic Condition and Weather

Information on the traffic condition and weather on the road section ahead is important for drivers to minimize delay as well as to avoid accident. Type of information needed by drivers include the following:

- Closure of road by wadi flood, traffic accident, road maintenance works etc.
- Traffic congestion in large cities or those caused by special event such as festival

- Recommended detour route
- Hazardous weather condition including heavy rain and possibility of wadi floods.

There are mainly two methods to transmit above information to drivers:

- Radio broadcasting
- Road-side information board with changeable messages

Provision of road/traffic information is very effective since all the vehicles are equipped with radio and drivers often listen to radio broadcasting. Where feasible and appropriate, designated frequency of radio broad casting is exclusively used for traffic information. Figure 13.5-3 (a) and (b) show examples of sign indicating radio frequency for traffic information and traffic information board.

(a) Sign showing Radio Frequency for Traffic Information

(b) Traffic Information Board

[Message: Be aware of strong wind!]

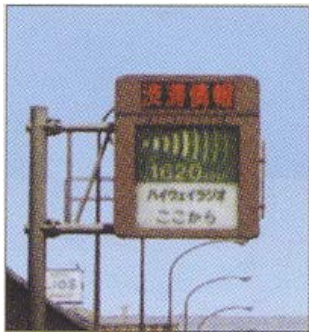


Figure 13.5-3 Sign of Traffic Information Radio and Traffic Information Board

4) Medical Services

Medical services for those injured in traffic accidents or unexpected illness do not need to be directed exclusively to road users but any medical facility along the road can be used for this type of services. Necessity of such services is best illustrated by the case of a serious bus accident occurred on NR 31 near Hayma on 27 April 2004. In this accident, one passenger was killed and 13 passengers were seriously injured. Some the injured were transported to Nizwa for treatment. Usually, treatment of injuries caused by traffic accidents needs to be done as soon as possible. In critical cases, delay of treatment by 10 minutes may result in unnecessary death. Therefore, clinics/hospitals need to be located at appropriate intervals such as 100 km. Ambulance cars with crews trained for firsthand medical treatment should be stationed at these clinics/hospital. These clinics/hospitals for ordinary medical services for the local residents can be designated for emergency treatment for road accidents.

13.5.2 Michi-No-Eki (Road Station) or Highway Oasis

Road Station, or Michi-No-Eki, is a comprehensive form of road user services as described in the previous subsection. It is a large-scale rest area equipped with toilet, restaurant, public telephone and shops of souvenir and local products (often with gas station). This type of facility was first started in Japan a little more than 10 years ago. Figure 13.5-4 shows conceptual illustration and a photo of an example of Road Station.

One of the most often, and sometimes serious, problem for drivers and passengers is toilet. The idea of Mici-No-Eki started from providing clean and comfortable toilet to travelers. This idea is now developed to more positive idea of "promoting the communication between travelers and local people". One of the important features of Michi-No-Eki is that local products are sold by local people in the kiosk located in the Road Station. This is expected to let local products known to the other parts of the country and promote local industrial activities.

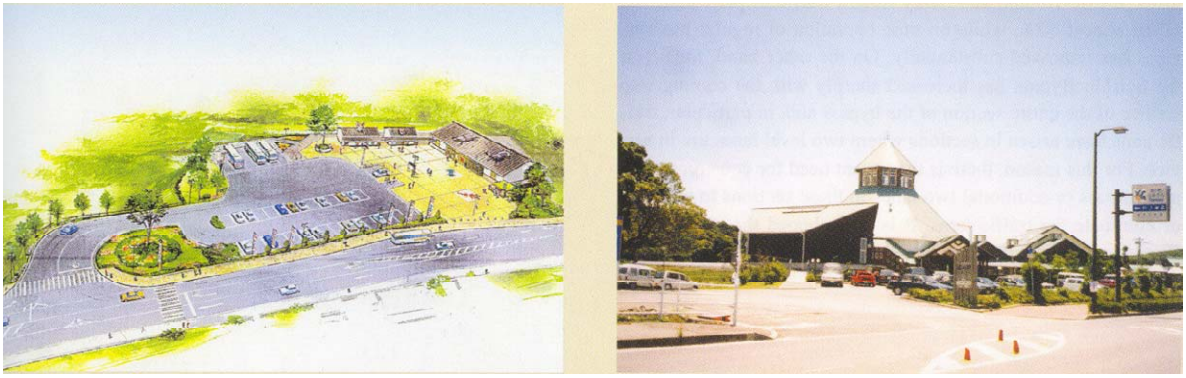


Figure 13.5-4 Conceptual Illustration and Example Photo of Michi-No-Eki (Road Station)

Separate from the idea of Road Station, there is another idea to encourage local industries called "One Village, One Product", or "Isson Ippin Undou", proposed by Mr. Hiramatsu, then the Govenor of Ooita Prefecture, Japan more than 10 years ago. This idea is to encourage each remote villages to produce at least one local product unique to that village and activate the remote village which otherwise may be "sleeping".

The ideas of Michi-No-Eki combined with "One Village, One Product" are expected to encourage local industries in remote villages not only in Japan but in some other countries in Asia. World Bank has also noticed the significance of these ideas and has done some survey on possibility of introducing similar ideas in developing countries.

Michi-No-Eki may be one of the measures which can be introduced to the Sultanate to promote rural economic activities of remote villages utilizing the strengthened function of road network.

"Highway Oasis" is the terminology used for the rest areas located along the national expressways in Japan. Function and basic idea (communication of travelers and the local people) of Highway Oasis is same to those of Michi-No-Eki. Difference is that Highway Oasis is for national expressway and Michi-No-Eki is for other (ordinary) national highways. The name of "**Highway Oasis**" may be more suitable if similar facility will be constructed in the Sultanate.

13.6 INTELLIGENT TRANSPORT SYSTEM (ITS)

Owing to the advancement of technologies in various fields, as typically represented by IT (Information Technology), new system of road user services, combined with road maintenance, are becoming available. The entire scheme of such system of road user services and road maintenance is called Intelligent Transport System, or ITS. The followings are some examples of such new road user services being experimented and implemented in developed countries. These services may become appropriate or necessary in the Sultanate in the near future.

1) Concept of ITS

Figure 13.6-1 shows the conceptual illustration of ITS. ITS is constructed on the infrastructure such as communication satellite, GPS and mass data/information transmission system including optic fiber network.

Followings are some examples of ITS technologies which are being studied or experimented and expected to be applicable to roads in the Sultanate.

1) Warning of Hazard at "Blind" Curve

Figure 13.6-2 schematically shows the warning system of hazard at "blind" curve. When, there is a vehicle stopping on a carriageway which is not visible from the coming vehicle, such at blind curve, the sensor installed at such location detects such vehicle and turns on the warning sign located well ahead. This may be effective to reduce the chances of accidents on the roads in mountainous terrain in the Sultanate.

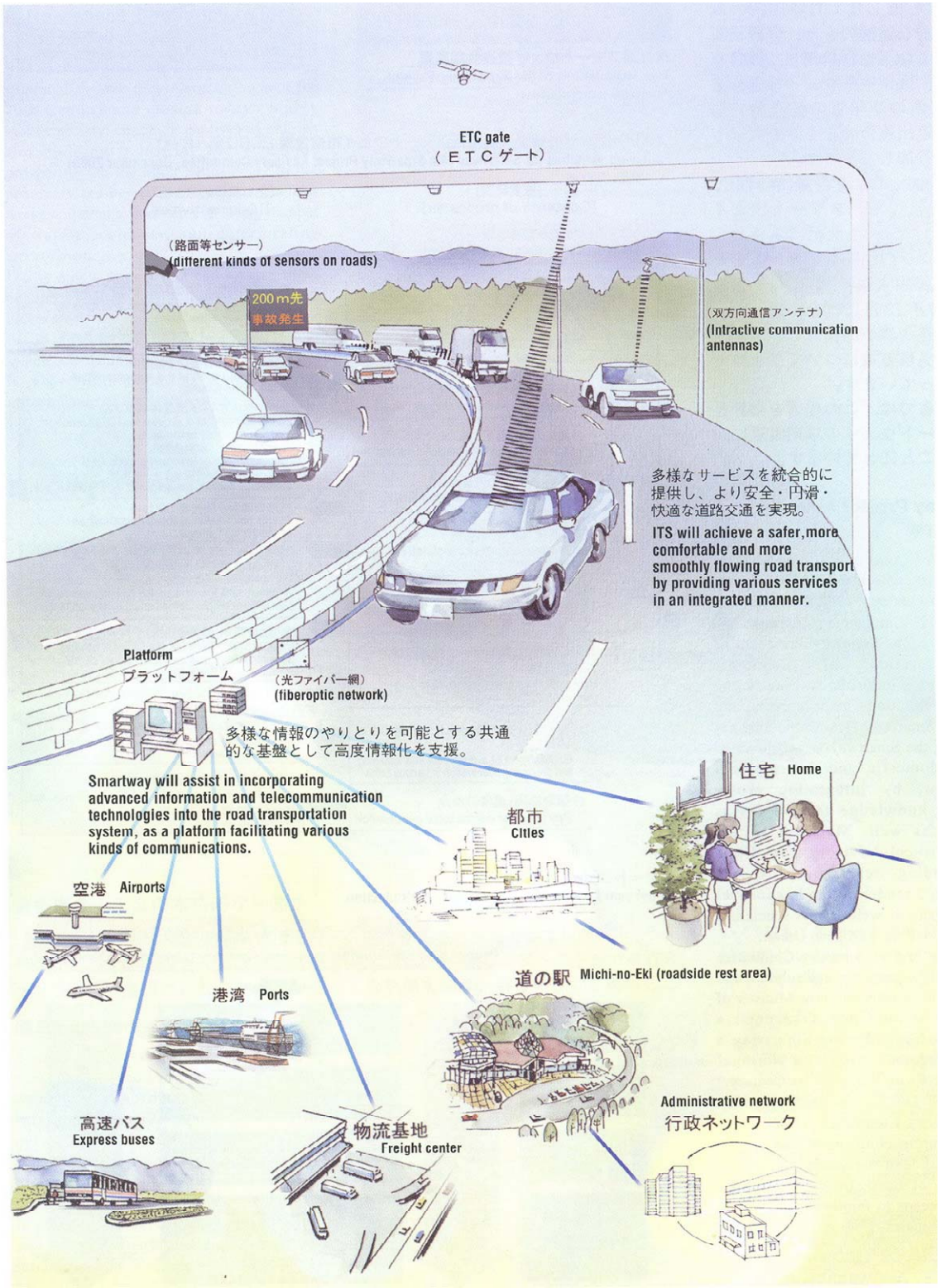


Figure 13.6-1 Conceptual Illustration of ITS

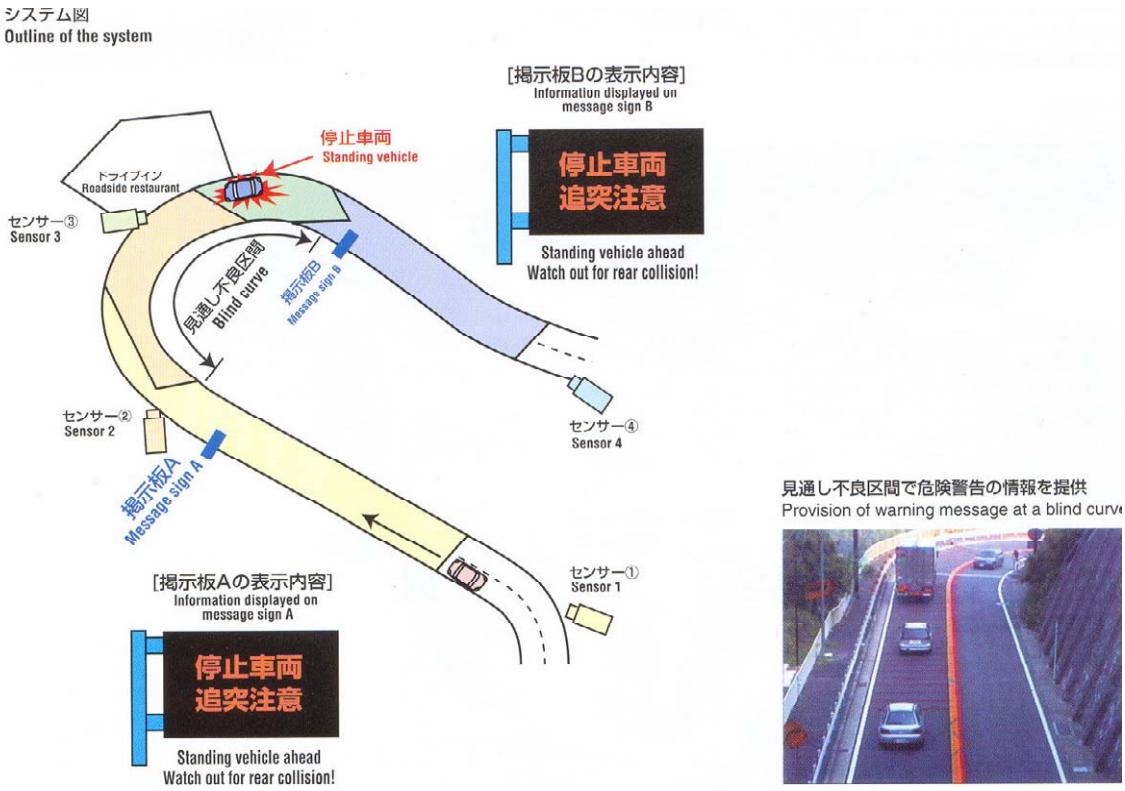


Figure 13.6-2 Warning System of Hazard at Blind Curve

2) Detection of Cut Slope Failure

Figure 13.6-3 shows the system of detection of cut slopes failure utilizing GPS. Movement of critical cut slopes located distant from maintenance office is observed utilizing GPS. The data of movement of cut slope are transmitted to the nearby maintenance office so that the maintenance office can take precautious actions. This system is being used in practice in Japan and may be useful for similar situation in the Sultanate.

3) Observation of Hazardous Natural Phenomena

Figure 13.6-4 shows the system of hazardous natural phenomena. In the particular case of the example shown here, rough wave of sea is observed for traffic safety of raods running adjacent to the coast. The same system may be adopted to observe cirtical wadi crossing of important roads in the Sultanate.

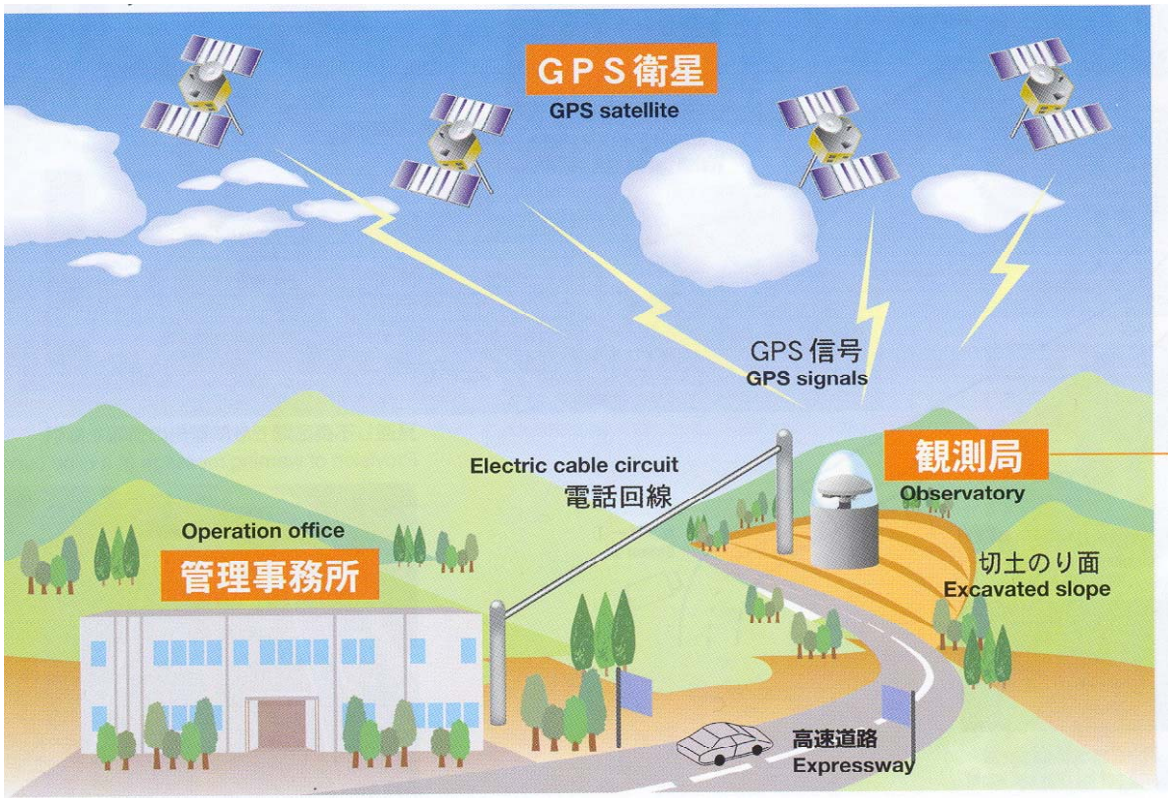


Figure 13.6-3 Detection of Cut Slope Failure

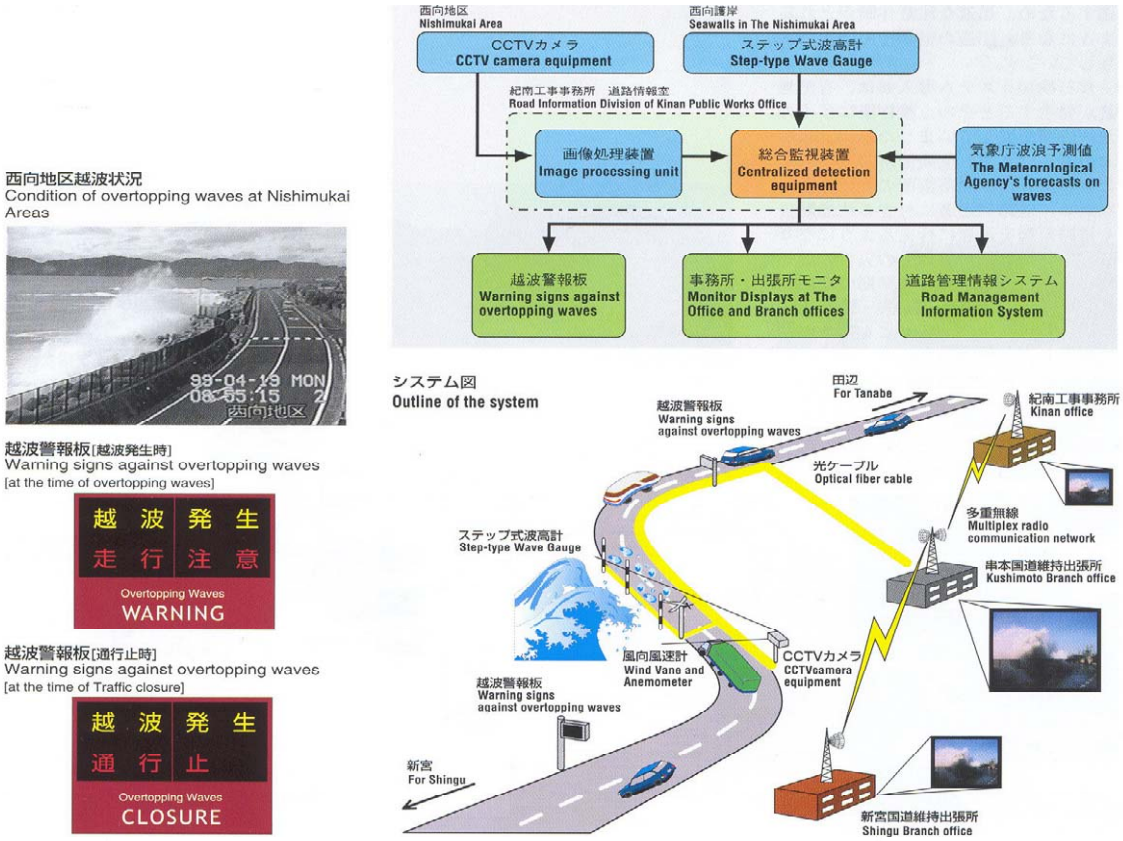


Figure 13.6-4 Observation of Hazardous Natural Phenomena

4) Monitoring the Movements of Special Vehicles

Figure 13.6-5 shows the system of monitoring the movements of special vehicles such as heavy vehicles which need to travel designated route. This system may be applicable in the Sultanate to monitor the heavy vehicles whose travel routes have to be regulated.

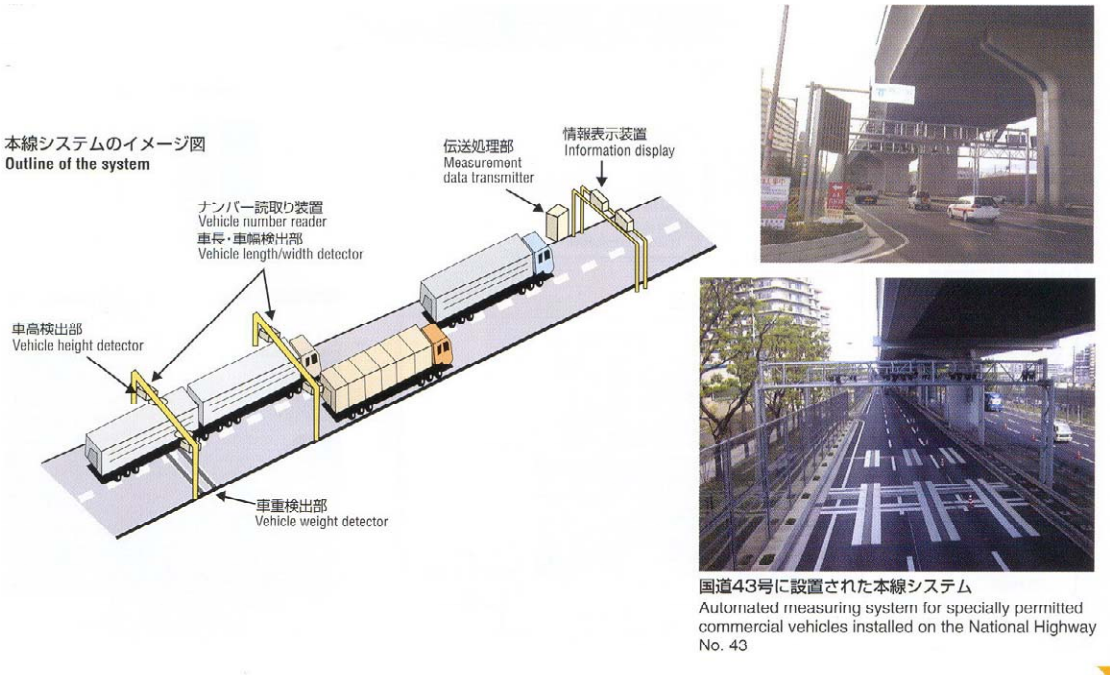


Figure 13.6-5 Monitoring System of Movement of Special Vehicles

13.7 ORGANIZATION PLAN

This Section basically discusses the organization from viewpoint of maintenance, however, some considerations are given also to construction and other activities of DGR. Therefore, the organization plan discussed here can be regarded as organization plan for the entire Master Plan.

13.7.1 Present Organization of DGR

1) Present Organization

The present organization of DGR and DGC is described in Section 4.2. DGR and DGC are currently staffed with about 230 persons and 106 persons, respectively. DGR has eight Regional Centers to monitor conditions of roads.

2) Assessment and Identification of Problems of Present Organization

Government institution in charge of road administration usually needs to have the following major functions:

- Planning: Planning of road network and projects
- Construction: Design, tendering/contracting road construction works and management of road projects including budget management
- Maintenance: Maintenance of roads under the jurisdiction of the institution; actual road maintenance works may be contracted to private firms
- Administration and other non-engineering works

In this sense, the present organization of DGR is equipped with basically necessary departments and sections. Accordingly, there is very little room to add new departments or sections urgently.

In addition, DGR already has already undergone large-scale restructuring in which design and maintenance works are now out-sourced. Accordingly, the “slimness” of the present organization is comparable to developed countries and there is almost no room to make the present organization “slimmer”.

In the future, however, there is some need for new departments and sections, as discussed in Subsection 13.5.3, in view of providing better services to road users.

3) Problems of Institutional Capacity and Work Procedures

Although the present organizational structure of DGR is equipped with basically necessary departments and sections and is sufficiently slim, the problems as described in the following subsection are identified on its capacity and work procedures, through observations and discussions with DGR.

Unless these problems are solved, mere addition of departments or sections will not yield expected outcome.

(i) Lack of proper job descriptions for departments and sections
(ii) Poor coordination between departments within DGR, between Ministry Proper departments and departments in DGR, and between Ministries
(iii) Insufficient accumulation of data and information
(iv) Insufficiency in competent/qualified staff
(v) Insufficient capacity of regional departments
(vi) Insufficient usage of computerized system and network in DGR Headquarters
(vii) Vicious circle of insufficient institutional capacity inefficient work and unnecessary workload

These problems are explained below:

(i) Lack of proper job descriptions for departments and sections.
Although the function of Director General of DGR is stipulated in the Royal Decree for establishment of the MOT&C, there are no job descriptions of Departments and Sections of DGR. This situation leads to the situation where some information is not available and proper planning or implementation of jobs is hampered. One example is that no section has complete data of entire DGR budget

(ii) Poor coordination between departments within DGR, between Ministry Proper departments and departments in DGR, and between Ministries.
Relevant information is not properly disseminated in DGR. For example, news of singing of contracts for road construction is often obtained not through DGR staff but through newspaper. This indicates that proper coordination is not practiced.

Of course, this matter cannot be solved by DGR alone or MOT&C alone, and it may need considerable time to rectify this problem. However, effort should be made to improve the situation.

(iii) Insufficient accumulation of data and information.

As exemplified by the cases of record of damages due to floods of wadis, there are several types/categories of data/information essential to planning of roads. Collection and analysis of data/information on the actual road is the first step to solve the problem but necessary data are lacking. These needed data/information include the following:

(i) Traffic volume database
(ii) Pavement conditions (road inventory data)
(iii) Record of disaster on roads (wadi flood, slope failure, sand dune problems,)
(iv) Other problems occurring in daily maintenance which needs studies.

(iv) Insufficiency in competent/qualified staff

Although experience can substitute or supplement basic education in engineering to certain extent, experience cannot cover all the expertise required for DGR. In this context, the number of qualified staff in DGR is insufficient. Table 13.7-1 shows the composition of DGR staff by educational background, estimated from the titles indicated in the staff list.

Table 13.7-1 Composition of DGR Staff by Educational Background

	DGR Total (A)	Dept of Adm. & Fin. (B)	Other Dept			
			Engineer	Surveyor	Others	Total (C=A-B)
No of Staff	230	51	29*	37	113	179
%	-	-	16.2	20.6	63.1	100

* Include DG and Directors

As shown in the table, nearly two thirds (2/3) of the staff in engineering departments are without high educational background. Now that all of actual works of maintenance, design and study are contracted out and main tasks of DGR staff is to supervise, advise and make decisions for the matters which can not be done by the contractor or consultant, DGR staff is required to have good knowledge on the basic theories. Accordingly, percentage of staff with higher educational background should be increased.

DGR is currently employing seven expatriate experts to supplement insufficiency in the capacity of Omani staff. However, they are stationed in Muscat and often need to travel for several hours to inspect the sites of construction or maintenance resulting in inefficient utilization of their expertise.

(v) Insufficient Capacity of Regional Road Departments

Table 13.7-2 shows the list of Regional Departments and their composition of staff. The percentage of engineering staff with higher educational background (Engineer and Surveyor) including management (Director) is less than 20 %. This is supposed to be resulting in insufficient supervision of maintenance works implemented by the contractors.

It is desired that supervision of both construction and maintenance works are undertaken by Regional Departments so that supervision engineers can visit the sites frequently. But this is not possible because of the limitation of capacities of regional departments.

Table 13.7-2 Regional Road Departments and Number of Staff

Name of Region	Location	Paved Road Length in Charge (km)**	Number of Staff by Category				
			Manage	Engineer*/ Surveyer	Admini-strative	Others	Total
Musandam	Khasab + Daba	115	1	(1) / 2	1	9	13
Al Batinah North	Sohar	1,198	1	(1) / 3	2	15	21
Al Batinah South	A'Rustaq		1	0 / 2	2	12	17
A'Dhahirah	Ibri + Al Buraymi	638	1	(1) / 3	4	17	25
A'Dakhliyah	Nizwa	1,186	1	(1) / 3	1	8	13
A'Sharqiyah North	Ibra	933	1	0 / 2	2	9	14
A'Sharqiyah South	Sur		1	0 / 2	1	5	9
Al Wusta	Hayma	1,100	-	0 / 1	0	5	6
Total (Percentage)		5,170	7 6.0 %	(4)/18 (3.4)/ 15.3 %	13 11.0 %	80 67.8 %	118 100.0 %

* ( ) shows that engineer is same person with the Manager

(vi) Insufficient Usage of Computerized System and Network in DGR Headquarters

Currently, computers are used only by a portion, but not by the majority, of the staff of DGR. Even many professional (university graduate or equivalent) staff members of DGR are not equipped with personal computers. It is evident that computer cannot completely replace human beings, but it is also evident that computer can greatly improve efficiency of various types of works. In view of scarcity in the number of personnel, introduction (and necessary training for usage of) computers and construction of LAN (Local Area Network) should be considered. The following are only few examples among the many types of works

for which efficiency can be enhanced by introduction of computer and LAN (LAN should be connected to the MOT&C Headquarters):

a. Accounting and Budget Management

By inputting the data of payment of projects, budgets of entire DGR and each project can be easily managed. These data can be used by various levels of staff by sharing the information via LAN.

b. Road Inventory Data

Road inventory data are essential information for both planning of new construction and maintenance of roads. Road inventory data need to be updated. Collection of field data can be conducted by employing local consultant firms. Collected data can be easily inputted to update inventory data if the inventory is recorded in computer. Also, the inventory data can be accessed by various staff of DGR by connecting to LAN.

c. Traffic Volume Database

Data of traffic volume are very basic data used in various areas including planning, design and maintenance of roads. It is recommended that DGR survey traffic volumes at designated locations periodically. The surveyed traffic data should be inputted in computer so that it can be easily used.

d. Maintenance Record

Record of maintenance works, such as overlay of pavement and cleaning of debris at the side ditches, can be recorded and accumulated in the computer. These data will become valuable data for future planning of maintenance.

e. Record of Wadi Flood and Other Natural Disaster

As stated in Section 11.1, accumulation of record of wadi flood on road is essential to establish a policy for design of wadi crossing. Similarly, accumulation of data/information of cases of other natural disaster is the essential first step to establish policy for the countermeasures for these natural disaster.

(vii) Vicious Circle of Insufficient Institutional Capacity, Inefficient Work and Unnecessary Workload

It is suspected that insufficient institutional capacity of DGR is resulting in inefficient way of work, which, in turn, create unnecessary or otherwise avoidable problems which finally worsen insufficiency of staff. This vicious circle can be illustrated as shown in Figure 13.7-1.

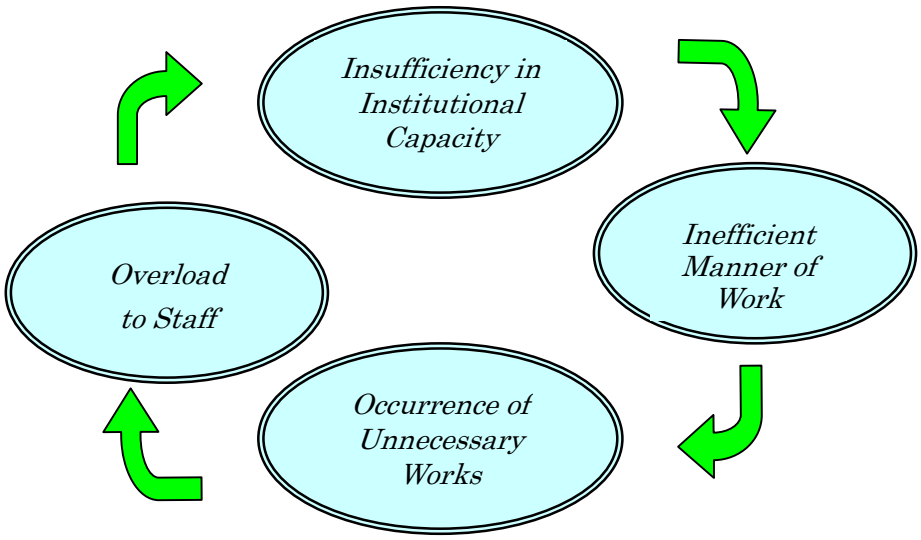


Figure 13.7-1 Vicious Circle of Insufficient Institutional Capacity

13.7.2 Basic Direction of Future Development of DGR Organization

In the past 30 years, the Sultanate achieved remarkable development of road network. This Study is to provide the basis for road development for the next 25 years. The further development of road network in the next 25 years is also expected to be remarkable. For this reason, the plan of organizational improvement should be prepared baring a vision for long future in mind. DGR is still young organization on its way to "full-fledged" governmental organization, and has great potential for future development.

1) Basic Ability Required for DGR

DGR needs sufficient knowledge to supervise, review, evaluate, advise and make decision on the outcome of consultants' works or maintenance or construction works, including the followings:

(i) Budget management; both for maintenance and construction; for project-base and for entire DGR
(ii) Contractual procedures including legal matters
(iii) Traffic Engineering
(iv) Highway Planning
(v) Highway Design
(vi) Pavement Design and Maintenance
(vii) Geotechnical Engineering

(viii) Bridge Engineering
(ix) Hydraulic Engineering

DGR needs to have experts among its staff whose expertise is equivalent or better than those of consultants or contractors.

1) Capacity Building; Development of Human Resources

Since insufficiency in qualified staff is the largest problem of DGR, the most urgent need for DGR organization is to establish well-organized plan for capacity building and implement it. The following items describe outline of the proposed programs of capacity building for DGR.

2) Recruiting

Currently, the number of annually recruited staff fluctuates every year as shown in Figure 13.7-2.

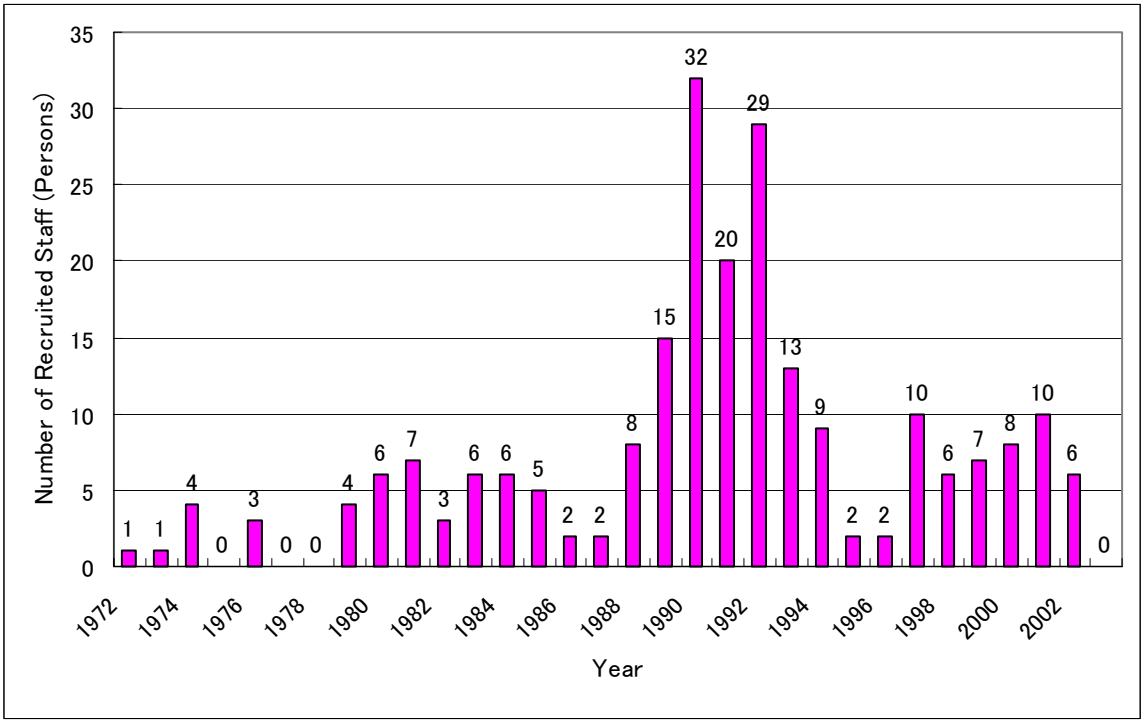


Figure 13.7-2 Fluctuation of Annual Recruitment by DGR

Large fluctuation in number of annual recruitment will result in disruption of continuity of staff experience level. When a staff member is transferred from one position to the other, another staff member who replace the new vacancy needs to have similar experience. Therefore, constant number of staff should be continuously maintained

from novice level to experienced level. For this reason, number of recruitment should be as constant every year as possible.

As explained later, About 150 engineers will be needed in the future for DGR. If DGR recruit 5 university graduates every year, DGR will have 5 x 25 = 125 persons of qualified engineer in addition to those who are currently working in DGR. It will be also necessary to supplement to those who will retire in the future. Therefore, it is recommended that DGR start recruiting 5 persons of university graduates every year.

Constant recruitment of university graduates are also beneficial for both universities and DGR for the following reasons.

- Universities (Department of Civil Engineering) can secure constant job opportunities for their graduates.
- With assurance of job opportunities, universities (Dept. of Civil Engineering) can attract good students.
- Good students will usually become good engineers and contribute to DGR.

3) Career Path

Table 13.7-3 shows typical level as engineer, corresponding position and years of experience for a university graduate engineer.

Table 13.7-3 Typical Level, Position and Years of Experience

Year	Position	Type of Assigned Work
1	Engineer	Assigned to regional office and assist the works of other engineers and learn the basic work procedures
2		Supervise construction or maintenance with advice of senior engineer
3		
4		Assigned to different type of projects (construction - maintenance - project administration) for wide experience in regional department
5		
6	Senior Engineer	In regional department, supervise construction or maintenance project or administering projects. Also advise younger engineers and assist chief of section.
7		
8		
9		May be appointed to HQ and oversee projects in nationwide basis or may be appointed as section chief in regional department
10		
11 – 15	Junior Manager	Appointed section chief in HQ or regional department and manage a small group of staff. Then, may be promoted to deputy director level.
15 or More	Manager, Senior Manager	Director of Departments in HQ or Regional Department

Before an engineer is promoted to junior management level as shown in the table above, he/she need certain experiences and practical knowledge. Figure 13.7-3 shows typical career path of an engineer working in governmental organization for road.

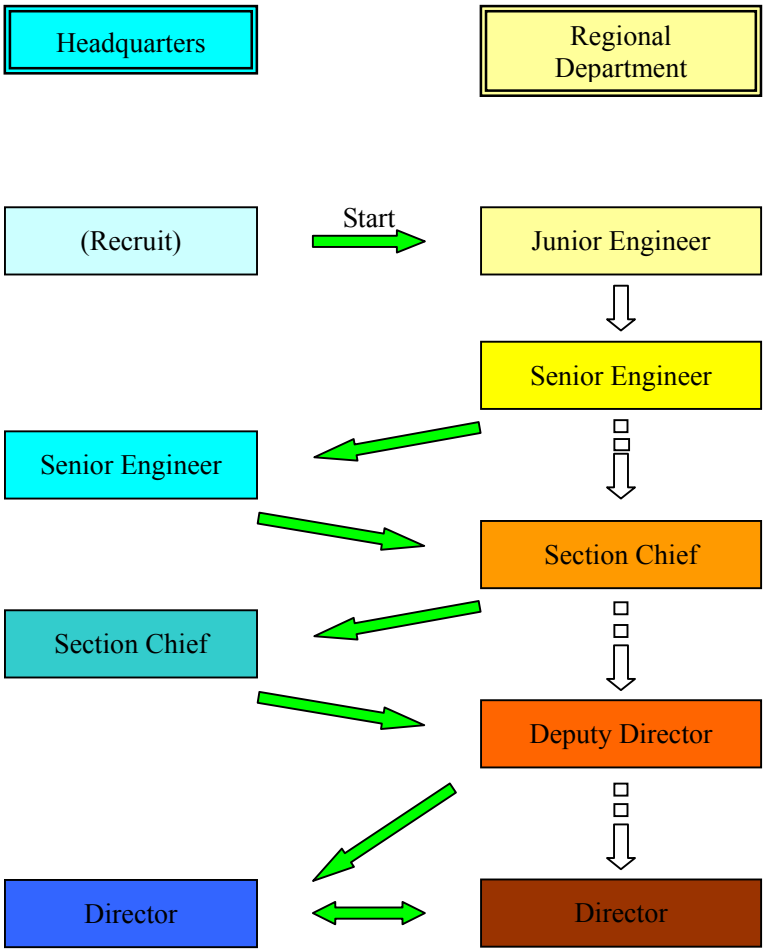


Figure 13.7-3 Typical Career Path for University Graduate Engineer

4) Training

Although on-the-job training is usually the most effective and efficient manner of training, Table 13.7-4 shows examples of contents of training courses for DGR staff (engineer) at different levels. The courses/subjects include those needed for the next step in the career path.

These trainings do not need to be implemented by sending staff abroad. Rather it is expected to hold these training periodically in DGR premises and inviting lecturers

form inside and outside of DGR as appropriate. Lecturers for some courses may be provided by some of the experienced DGR staff with proper educational background.

Table 13.7-4 Examples of Training Courses

Staff Level	Types of Trainee	Courses/Subjects
Junior Level	Up to 5 years after graduation from university	(1) Project management: Planning/design of road/ bridge, quality control, quantity control, budget management (project level) (2) Road planning: Regional planning and road planning, road planning (planned traffic volume, traffic capacity, transport economics, etc.) (3) Computer skills (4) Basic knowledge as civil servant: Preparation of documents, responsibility as government official (5) Basic knowledge as DGR staff: legislations related to road administration, tasks of DGR, work procedures, including coordination with relevant parties
Middle Level	5 yrs after graduation from university or more, up to Deputy Director level	(1) Personnel management (2) Budget management (department/DGR level) (3) Coordination with relevant parties
Management Level	Deputy Director and above	(1) National policy on development (2) Present situation of socio-economic development and future vision (3) Future perspective on national economy and road fund

Also, training should be given to staff without educational background needed for their work, such as accounting, computer and geotechnical engineering and other disciplines related highway engineering.

Further, even staff with higher educational background should be given periodical trainings on their expertise because the courses taught in university covers only basic theories and the knowledge acquired through these courses are not sufficient for practical courses. Periodical trainings are also necessary for renewal of the knowledge.

5) Usage of Computer

As discussed in Subsection 13.7.1 (v), the number of computers used in DGR is not enough. It is recommended to increase the number of computers so that each staff from engineer level and above has one unit of computer connected to LAN and internet.

6) Research and Development

There are several road engineering problems unique to the Sultanate. Such problems include;

(i) road maintenance in desert (sand dune) area;
(ii) road construction/maintenance in Sabkhah; and
(iii) design and maintenance of roads at wadi crossing.

These problems are not frequently encountered in other part of the world and there are very few information/data on these problems. Accordingly, research is needed on these subjects. These researches have to be conducted in the Sultanate with possible cooperation with other Gulf Countries. Within the Sultanate, DGR should consider to ask cooperation also from universities, especially national universities.

13.7.3 Proposed Organization

Future organization is proposed on the following premises:

(i) By year 2030, DGR will be responsible for maintenance of about 20,000 km of paved roads.
(ii) Even after majority of the existing track will be paved, there will be projects of additional construction of track roads and paved roads to further strengthen the function of road network.
(iii) Therefore, DGR need to maintain function to administer construction, strengthened function for maintenance.

1) Long Term Organization Plan (2021-2030)

Figures 13.7-4 (a) and (b) show proposed organizational structure of the DGR headquarters and regional departments to be implemented in the period of 2021-2030. The main strategies for the proposed organization are as follows:

- Better coordination with local governments (Wali Wilayah, etc.) and local people by strengthening the function of regional departments.
- Closer supervision of construction and maintenance projects by assigning engineers in regional departments.

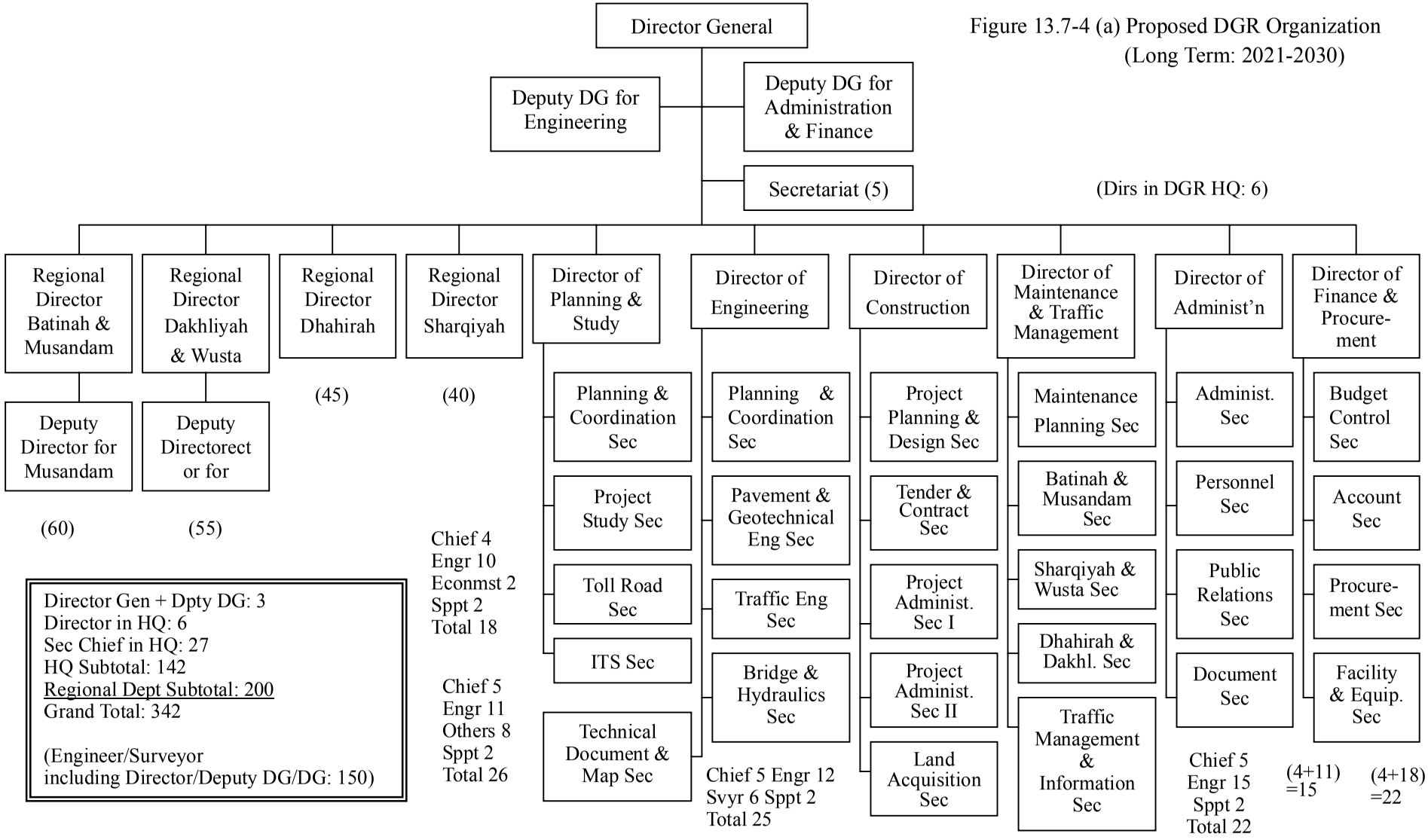


Figure 13.7-4 (a) Proposed DGR Organization
(Long Term: 2021-2030)

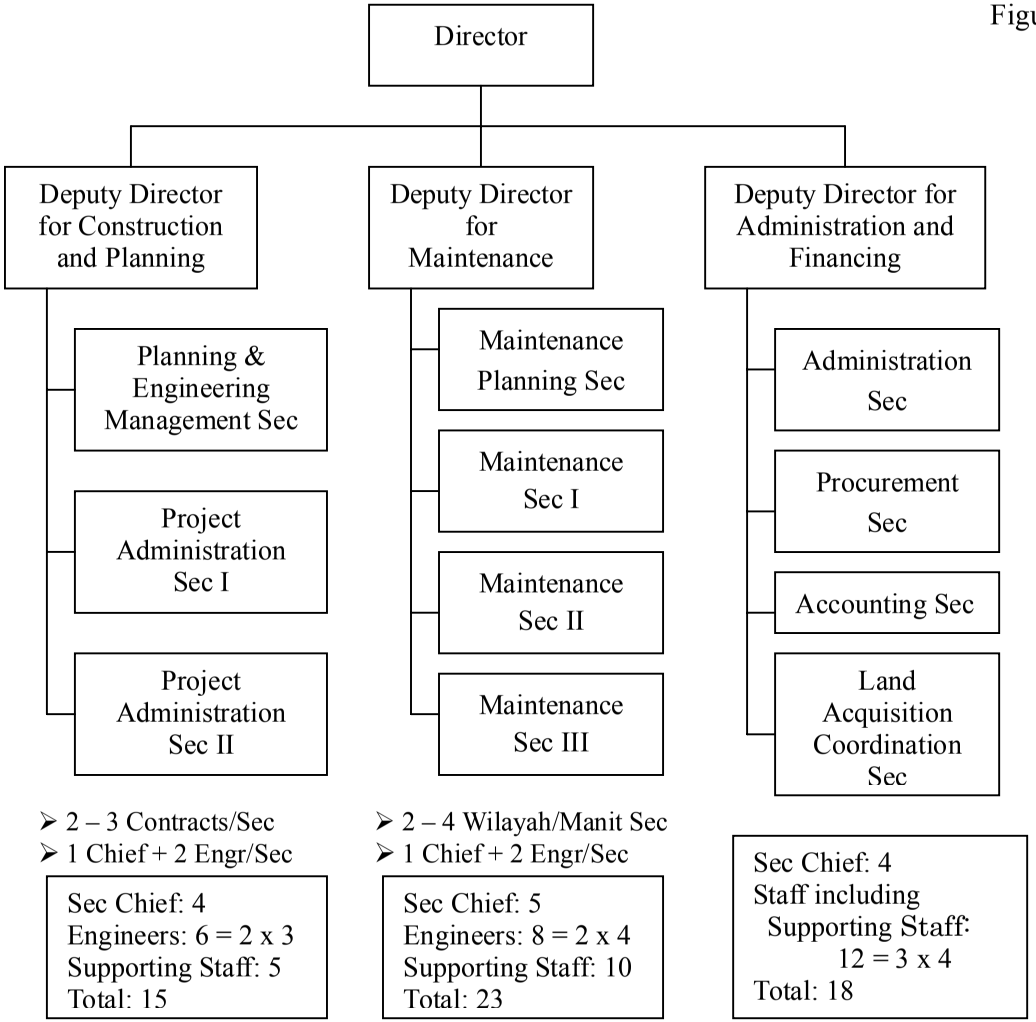


Figure 13.7-4 (b) Proposed DGR Organization
(Long Term: Regional Department)

Variation in Staff Size

Region	No. of Staff	No. of Engineer
Batiinah & Musandam	60	30
Dakhliyah & Al Wusta	55	25
Dhahirah	45	20
Sharqiyah	40	15
Total	200	90

Grand Total: 56

- Enlarged authorities of Regional Directors to plan, design and implement projects based on the local needs.
- Support for regional departments by the headquarter Departments to provide high-quality services.
- Examination of problems and preparation of draft for solution by qualified working-level staff to save time of management level staff who are to concentrate on high-level planning and policy matters.

Salient features of the proposed organization are as follows:

- Department of Engineering will be established to provide services of up-to-date technologies.
- Existing 8 regional road departments are united into 4 regional departments.
- Each regional department is equipped with maintenance division and construction division. Actual supervision of construction and maintenance is the responsibility of regional department.
- Regional departments are responsible to prepare its own construction plan and maintenance plan in consultation with relevant local authorities and people.
- Toll Road Section and ITS Section will be established under Department of Planning and Study to handle these new tasks.
- As for construction projects, Department of Planning and Study handles the projects up to F/S stage. As soon as implementation of the project is approved, the works related to implementation of projects including Detailed Design are handed-over to Department of Construction.
- If "Decentralization Policy" is adopted by the Government, as being the cases in many developed/developing countries, this Long Term Plan can easily adapt to such situation because considerable functions are delegated to regional departments.

In this plan, total number of DGR staff is about 340 among which 150 are engineers with university degrees or equivalent qualifications (surveyors with sufficient training and experience). If DGR recruits 6 persons of graduates from university (or technical junior college for surveyors) in the field of civil engineering as proposed in Subsection 13.7.2 Item (2) above, this required number of qualified engineers can be secured in 25 years.

2) Basic Job Descriptions of Departments and Sections

Table 13.7-5 presents basic job descriptions of departments and major sections in the proposed organization chart.

Table 13.7-5 Job Descriptions of Departments and Major Sections

Organization/ Position	Job Description
Regional Department	Assumed Task: Maintenance of around 5,000 km of road and around 5 construction projects covering 5 to 15 Wilayahs in the region
Director	・ Report to DG and Deputy DG ・ Supervise & Represent the Regional Department ・ Approve the matters of the Regional Department, except the matters which need approval of DG/Deputy DG ・ (Make final decision after coordination with Wali Wilayah and other relevant parties and report to DG/Deputy DG.)
Deputy Directors	・ Supervise sections under him/her ・ Assist the Director and report to him ・ Coordinate with local relevant parties
Maintenance Planning Section	・ Preparation of draft for maintenance plans, including prioritization and selection sections to be rehabilitated, cost estimates and implementation plan ・ Coordination among maintenance sections as well as with sections other than maintenance sections
Maintenance Sections	・ Each section cover 2 to 4 Wilayahs depending on the area and road length ・ Supervise the consultant and contractors for maintenance ・ Patrol and monitor road conditions on routine and ad hoc basis, such as after wadi flow
Planning & Engineering Management Section	・ Selection and prioritization of construction projects ・ Preparation of budget plan ・ Budget management ・ Coordination among project sections as well as with sections other than project sections ・ Supervision of design done by consultant
Project Administration Section	・ Administration of construction projects ・ Issuance of Variation Orders ・ Supervision of Quality Control done by Consultants ・ Quantity Survey and issuance of certificates
Administration Section	・ General administration of Regional Department ・ Personnel matters ・ Public relations & documents ・ Other miscellaneous matters
Accounting Section	・ Keeping record of disbursement of the Regional Department and report to the Accounting Section of HQ
Procurement Section	・ Procurement for the Regional Department
Land Acquisition Coordination Section	・ Coordination with local people and assistance to HQ concerning land acquisition

Table 13.7-5 Job Descriptions of Departments and Major Sections (Continuation)

Department of Planning & Study	・ Planning for entire engineering departments in DGR ・ Coordination among Departments in HQ and regional departments ・ Organization and personnel planning of engineering departments ・ Planning of new projects ・ Any engineering matter which is not under jurisdiction of other departments
Planning & Coordination Section	・ Prepare draft of planning for entire engineering departments in DGR, including organization and personnel planning ・ Prepare draft of 5YDP ・ Coordination among engineering departments ・ Coordination with MOT&C Departments and outside of MOT&C concerning engineering matters ・ Collection, maintenance and dissemination of engineering data
Project Study Section	・ Supervise F/S done by consultant ・ Carry out Pre-F/S as necessary ・ Study on transport economics
BOT Section	・ Administer BOT and other project with private participation
ITS Section	・ Study on introduction of ITS (Intelligent Transport System)
Department of Engineering	・ Introduction and application of most appropriate technologies in road construction and maintenance ・ Advise regional departments and other departments on technological matters ・ Research and development of new technologies in corporation with universities and other countries
Planning and Coordination Section	・ Prepare draft of business plan of the Department of Engineering ・ Coordination among the sections in the Dept of Engineering as well as sections in other departments ・ Prepare manuals and standards in coordination with Dept of Construction and Dept of Maintenance as necessary
Pavement & Geotechnical Section	・ Pavement design and maintenance ・ Embankment structure & Cut slope ・ Slope protection and pavement protection against wadi flow in cooperation of Bridge and Hydraulics Section ・ Measures for road in Sabkha area
Traffic Engineering Section	・ Traffic signs and pavement markings ・ Geometric design ・ Observation of traffic volume ・ Other matters of traffic engineering including IT
Bridge & Hydraulics Section	・ Bridge & culverts (design and rehabilitation) ・ Hydraulic design of bridges, culverts and Irish crossing ・ Slope protection and pavement protection against wadi flow in cooperation of Pavement and Geotechnical Section

Table 13.7-5 Job Descriptions of Departments and Major Sections (Continuation)

Department of Construction	・ Coordination with and advice to regional departments on the matters related to implementation of construction projects
Project Planning & Design Section	・ Management of budget for construction projects for entire DGR ・ Supervision of design done by consultant
Tender & Contract Sec	・ Preparation of tender documents ・ Tendering, including contract negotiation
Project Administration Sections I	・ Coordination with and advice to Regional Departments of Batinah & Musandam and Dhahirah on the matter related to implementation of construction projects
Project Administration Sections II	・ Coordination with and advice to Regional Departments of Dakhliyah & Al Wusta and Sharqiyah on the matter related to implementation of construction projects
Department of Maintenance & Traffic Management	・ Coordination with and advice to regional departments on the matters related to maintenance ・ Traffic management, including traffic control in cooperation with ROP and provision of traffic information (road closure due to accident, wadi flood etc, advice on detour route etc) ・ Road user services
Maintenance Planning Section	・ Preparation of maintenance planning, including budget planning ・ Coordination among the section in the department as well as the sections in other departments
Traffic Management & Information Section	・ Traffic management, including traffic control in cooperation with ROP and provision of traffic information (road closure due to accident, wadi flood etc, advice on detour route etc) ・ Plan & implementation of IT projects ・ Other road user services such as planning of ambulance, towing and repair services, fuel and food services and rest facilities
Batinah & Musandam Section	・ Coordination with and advice to Regional Departments for Batinah & Musandam on the matters related to maintenance
Sharqiyah & Al Wusta Section	・ Coordination with and advice to Regional Departments for Sharqiyah & Al Wusta on the matters related to maintenance
Dhahirah & Dakhliyah Section	・ Coordination with and advice to Regional Departments for Dhahirah & Dakhliyah on the matters related to maintenance
Department of Administration	・ General administration and miscellaneous affairs ・ Personnel maters ・ Public relations ・ Maintenance of official documents and legal affairs
Department of Finance & Procurement	・ Budget control of entire DGR ・ Accounting of entire DGR and report to the Accounting Dept of the Ministry ・ Procurement of materials, goods and equipment used in DGR ・ Management and maintenance of DGR buildings, vehicles, equipment and materials

3) Short Term Plan

Before Medium Term Plan is discussed, Short Term Plan is discussed to consider the urgent needs for organization. Medium Term Plan is proposed as the intermediate step between Short Term Plan and Long Term Plan.

Urgent Action Plan

Figure 13.7-5 shows proposed Urgent Plan for Organization of DGR, to be implemented in the period of 2005-2007. This plan is proposed to solve the very urgent problems of DGR which is weakness in supervision of both maintenance and construction. This plan is designed also to start action to be implemented in Short Term Plan as described later.

The basic objectives and strategies of the proposed organizational structure are as follows:

- Assign one senior engineer (with experience of about 5 years or more) to each of 4 regional department (RDpt) where there is no engineer and improve the capacity for supervision of maintenance works. (Currently, there are 4 RDpts which has engineers as the directors. Senior engineers are assigned to the regional departments other than those with engineers as the directors.)
- These maintenance engineers are under the control of regional directors but closely communicate with the Chief of Maintenance Planning & Management Section in the Headquarters (HQ).
- Two teams consisting of one engineer and one surveyor (or junior engineer), respectively, are stationed in two RDpts to strengthen supervision of consultants and contractors of construction projects. The RDpts where construction supervision engineers will be stationed should be selected among the ones located remote from Muscat and close to as many sites of construction projects as possible. This is the test case and the start of similar assignment of construction supervision engineers in each regional department, as planned in the Second Step Short Term Plan.
- Construction Supervision Engineers (CSEs) are to follow the direction of the regional directors concerning administrative maters, but directly report to the Chief of Project Administration Section in HQ concerning the supervision of the projects.

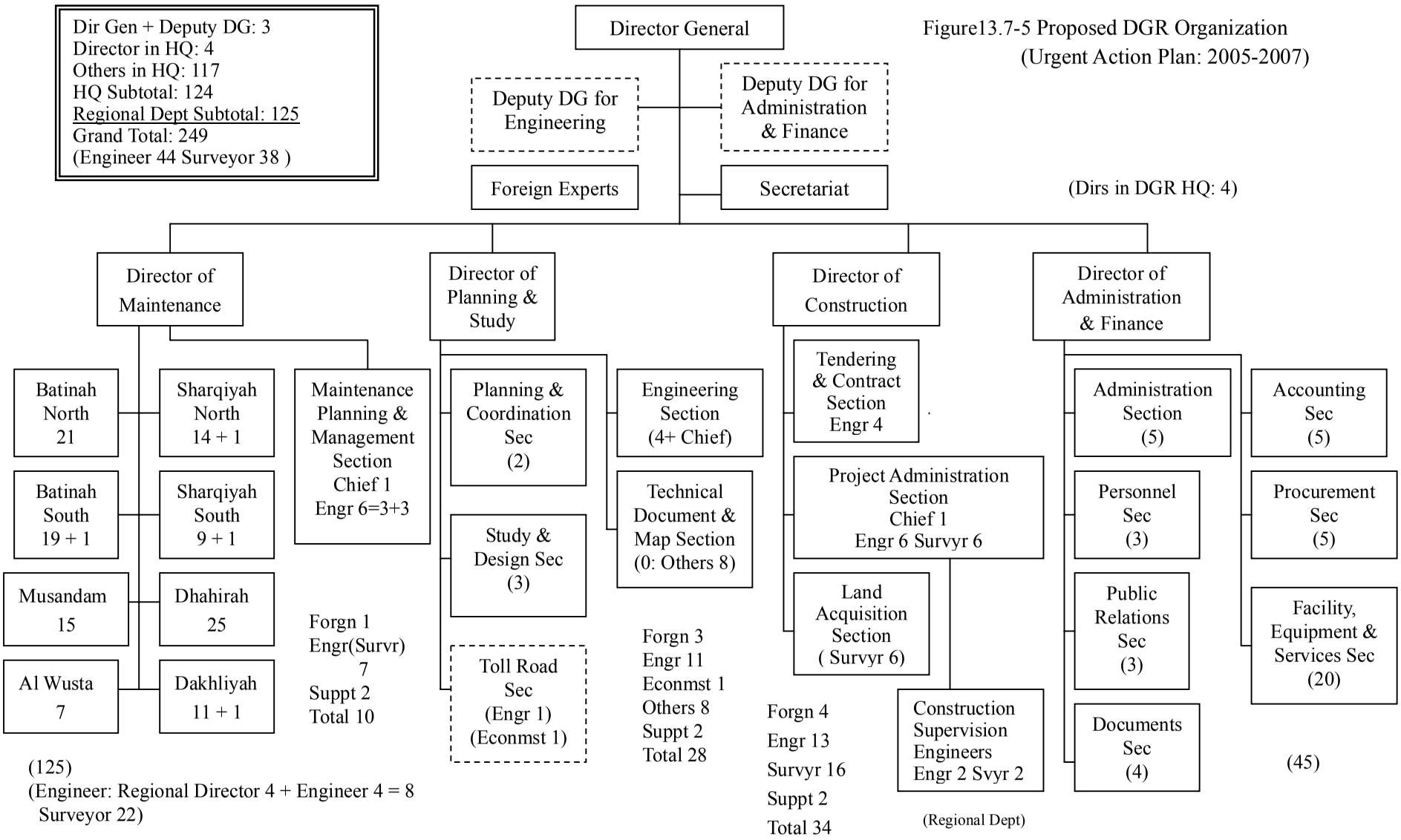


Figure13.7-5 Proposed DGR Organization
(Urgent Action Plan: 2005-2007)

- At HQ level, Maintenance Planning & Management Section is clearly defined and one Chief is appointed. This section is responsible for formulating nationwide maintenance plan based on the proposals from RDpts.
- This section is also responsible for daily advice and supervision of the works related to maintenance conducted by regional departments
- Toll Road Section is created under Dept of Planning and Study in preparation of toll road operation of Quryyat-Sur Road (NR 17) which is expected to be completed in year 2007. This section will consist of one highway/civil engineer and one transport economist cum financial analyst.
- Engineering Section is newly established also under Dept of Planning Study. This section will handle highly technical problems. Therefore, the staff in this section should have good academic qualification as well as practical experience of supervision of project administration and design. New graduates from university may be recruited and assigned but they need to be sent to universities or private consultants with special themes such as “bridge design”, “highway design and construction supervision” and “analysis of traffic accident black spots and design of traffic safety measures”.
- Recommended types of expertise to be provided by Engineering Section in its early stage are as follows:
- Present “Project Follow-up and Laboratory Section” and “Quantity Survey Section” are united into “Project Administration Section”. This section consists of one Chief, 3 Senior Engineers, 3 Junior Engineers and 6 Surveyors, at the time of its start.
- Tendering and Contract Section is newly established to specialize preparation of tendering documents, tendering, contract negotiations and preparation of contract documents to be signed by higher authorities. This section shall consist of 2 Senior Engineer and 2 Junior Engineer.
- At HQ level, Maintenance Planning & Management Section is clearly defined and one Chief is appointed. This section is responsible for formulating nationwide maintenance plan based on the proposals from RDpts.
- This section is also responsible for daily advice and supervision of the works related to maintenance conducted by regional departments
- Toll Road Section is created under Dept of Planning and Study in preparation of toll road operation of Quryyat-Sur Road (NR 17) which is expected to be completed in year 2007. This section will consist of one highway/civil engineer and one transport economist cum financial analyst.
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supervision of project administration and design. New graduates from university may be recruited and assigned but they need to be sent to universities or private consultants with special themes such as “bridge design”, “highway design and construction supervision” and “analysis of traffic accident black spots and design of traffic safety measures”.

- Recommended types of expertise to be provided by Engineering Section in its early stage are as follows:
- Present “Project Follow-up and Laboratory Section” and “Quantity Survey Section” are united into “Project Administration Section”.
- Sections in the Department of Administration and Finance are restructured by assigning minimum numbers of staff with necessary skills. Those staff without particular staff are assigned to “Facility, Equipment and Services Section”.
- The total number of staff in the Department of Administration and Finance should be curtailed as much as possible. But this may involve a social issue. The target number for Short Term Plan (6 year period: 2005-2010) should be around 45 (decrease of 7 persons).

Short Term Plan

Figures 13.7-6 (a) and (b) show proposed Short Term Plan for Organization of entire DGR (Second Step) and regional departments, respectively, to be implemented in the period of 2008-2010. This plan is the second step following the Urgent Action Plan (UAP) and continuation/extension of UAP. The basic objectives and strategies of the proposed organizational structures are as follows:

- Assign one senior engineer (with experience of about 5 years or more) to each RDpt (2 engineers to RDpts where directors are not engineers) and improve the capacity for supervision of maintenance works.
- When any difficult problem beyond the capacity of maintenance engineer and regional director arises, then, the problem is brought to Maintenance Planning & Management Section of HQ.
- Teams consisting one engineer and one surveyor (or junior engineer), respectively, are stationed in regional departments to strengthen supervision of consultants and contractors. The regional departments where construction supervision engineers will be stationed should be selected among the ones located remote from Muscat and close to as many sites of construction projects as possible. This is the test case and the start of similar assignment of construction supervision engineers in each regional department, as planned in the Second Step Short Term Plan.

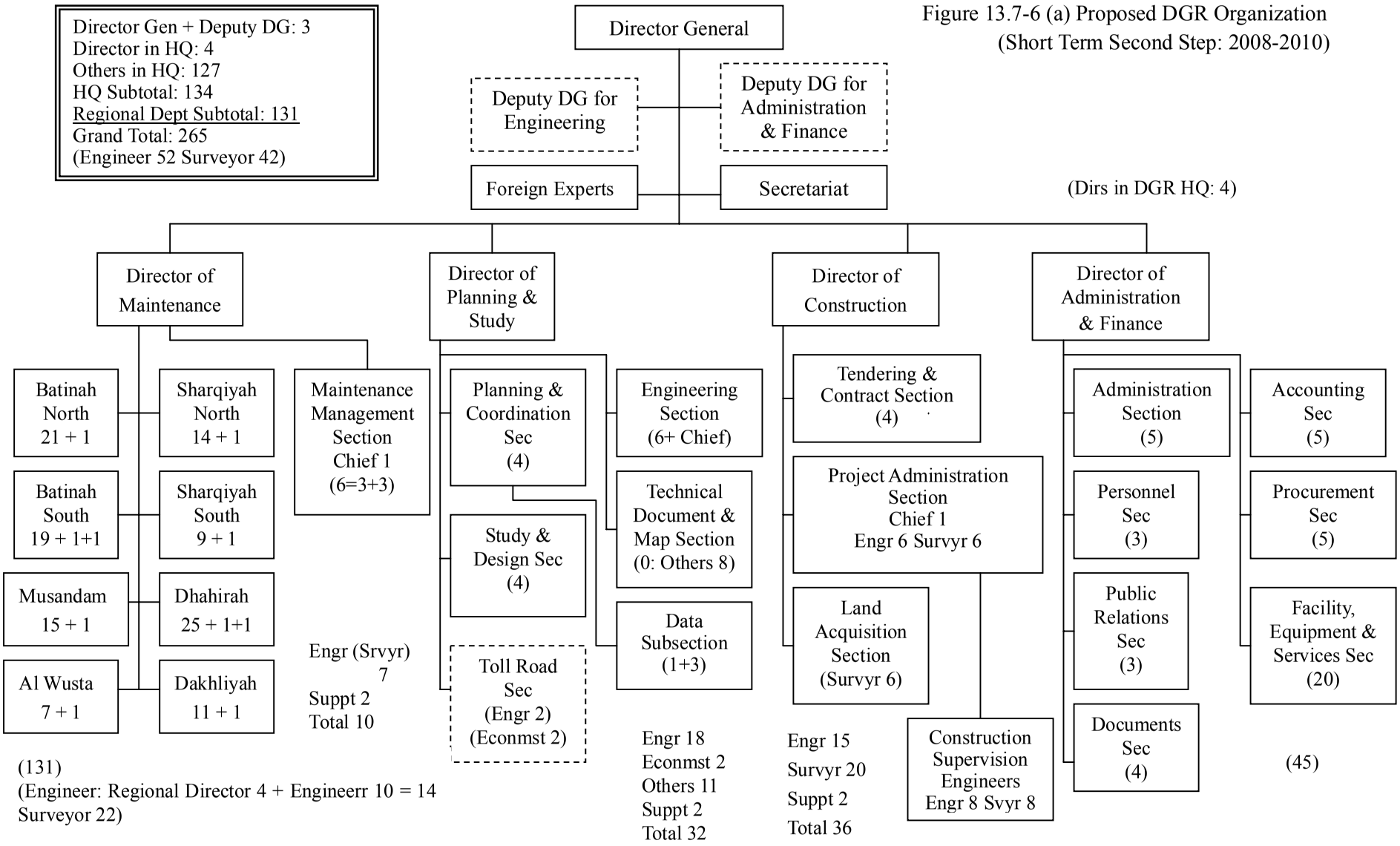
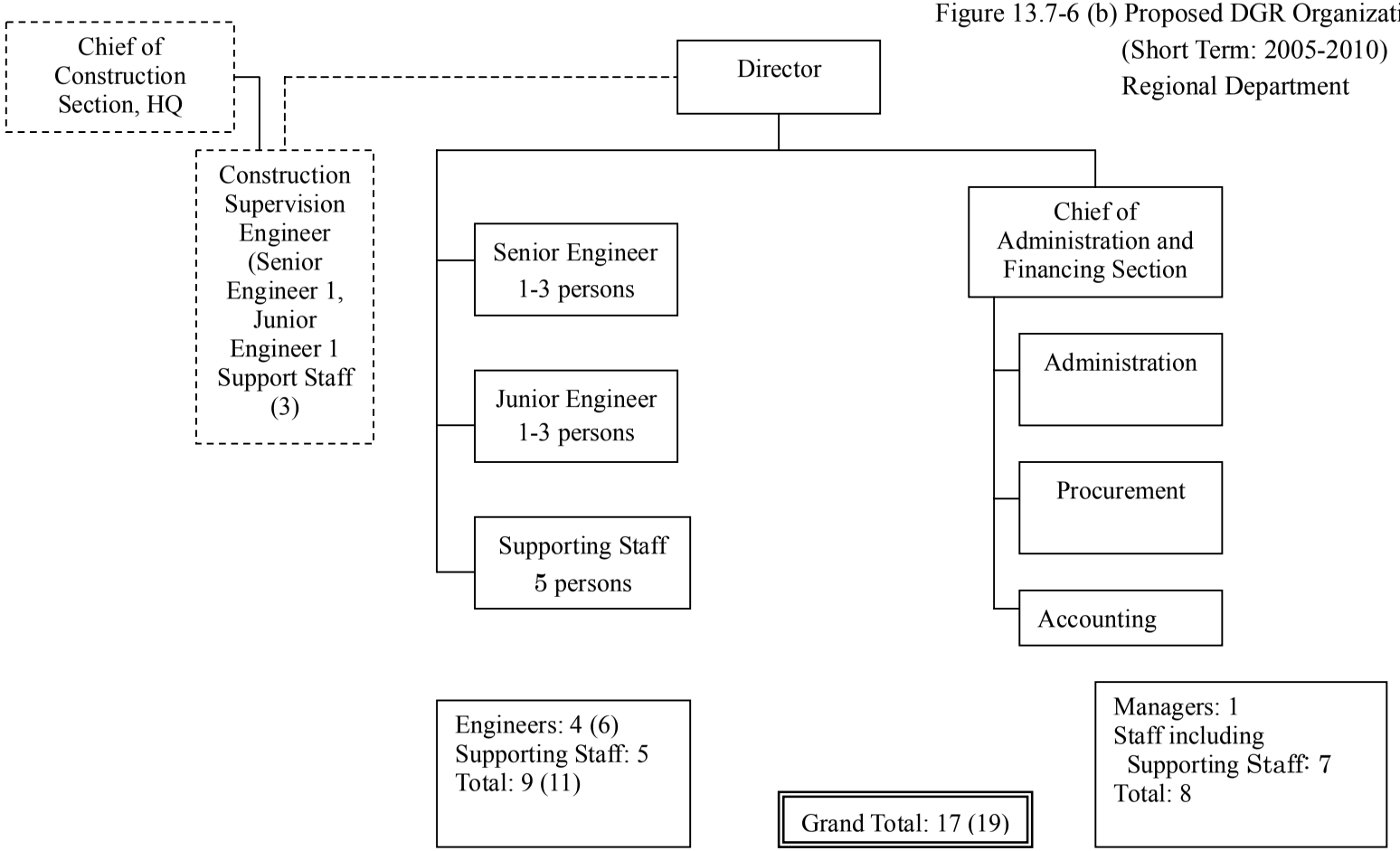


Figure 13.7-6 (a) Proposed DGR Organization
(Short Term Second Step: 2008-2010)

Figure 13.7-6 (b) Proposed DGR Organization
(Short Term: 2005-2010)
Regional Department



4) Medium Term Plan

Medium Term plan is prepared as a plan to be implemented in the period year 2011 to 2020. This plan is the transitional organization between Short Term Plan and Long Term Plan. Substantial parts of Long Term Plan are nearly completed in Medium Term Plan. However, the total number of qualified staff is still not sufficient compared to Long Term Plan while the total length of paved roads to be maintained by DGR is also less than that in Long Term Plan by about 4,000 km.

Figures 13.7-7 (a) and (b) show Medium Plan for organization of DGR and RDpts. Based on the above considerations, main features of Medium Term Plan are as follows:

- RDpts are staffed with 5 to 15 engineers for maintenance sections and construction sections, respectively, depending on the length of maintained road and number of construction projects.
- Regional directors supervise constructions sections and maintenance sections in their RDpts and are authorized to make decision on ordinary matters and required to report to DG/Deputy DG and consult with the relevant director(s) in HQ only on important matters.
- Thus, DG, Deputy DGs and Directors in HQ can more concentrate on high-level planning or policy matters for the more advance stage of road network development.
- ITS Section is established under Dept of Planning and Study with 1 Chief and 2 engineers and start study for future introduction of ITS.
- Toll Road Section is strengthened with 1 Chief, 2 engineers and 2 transport economist (or 1 transport economist and 1 financial analyst).
- Engineering Section is strengthened and promoted to Engineering Department with 5 sections and provide desired technical support to other Departments in HQ as well as RDpts. Each section consists of 1 Chief and 3 engineers (1 senior, 1 middle-level and 1 junior).
- Construction Department consists of 5 sections. Project Planning and Design Section is newly established to supervise deign works done by consultant as well as to be responsible for budget management and preparation of annual construction plans as described in the job descriptions for Long Term Plan in Table 13.7-5.
- “Department of Maintenance” is renamed as “Dept of Maintenance and Traffic management” and Traffic Management and Information Section is established under the said department. The function of Traffic Management and Information Section is presented in the job descriptions for Long Term Plan in Table 13.7-5.

- Maintenance Planning Section is newly established under Department of Maintenance and Traffic management and is responsible for preparation of future maintenance plan as well as other jobs as presented in the job descriptions for Long Term Plan in Table 13.7-5.
- Department of Administration and Finance is divided into Department of Administration and Department of Finance and Procurement in view of expected increased responsibilities and authorities on budget management in the future. Sections in these departments are expected to be staffed with skilled staff and the total number of these departments will be further decreased from that in Short Term Plan. (Decrease by 8 persons in 10 years)
- All the foreign experts are replaced by Omani engineers

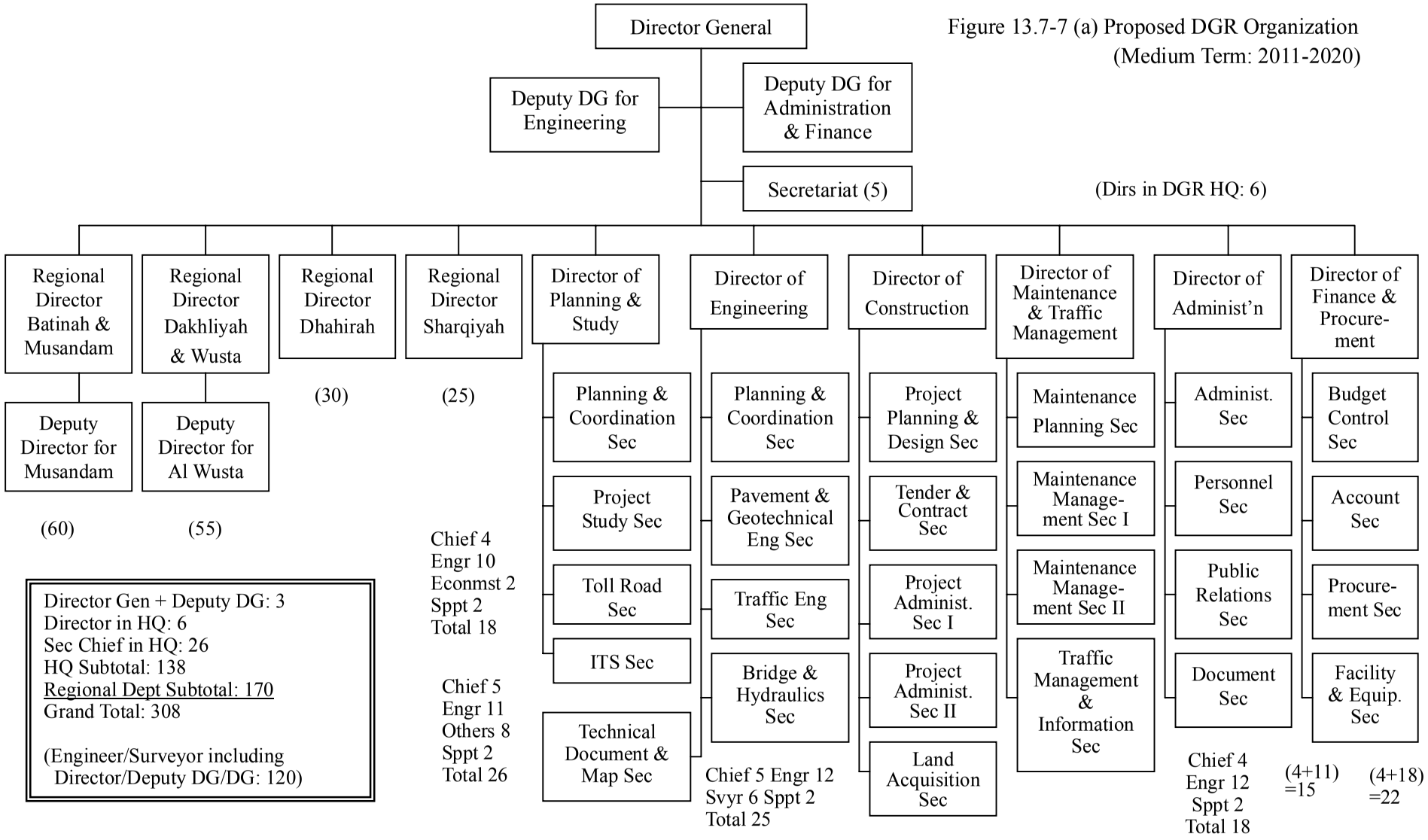
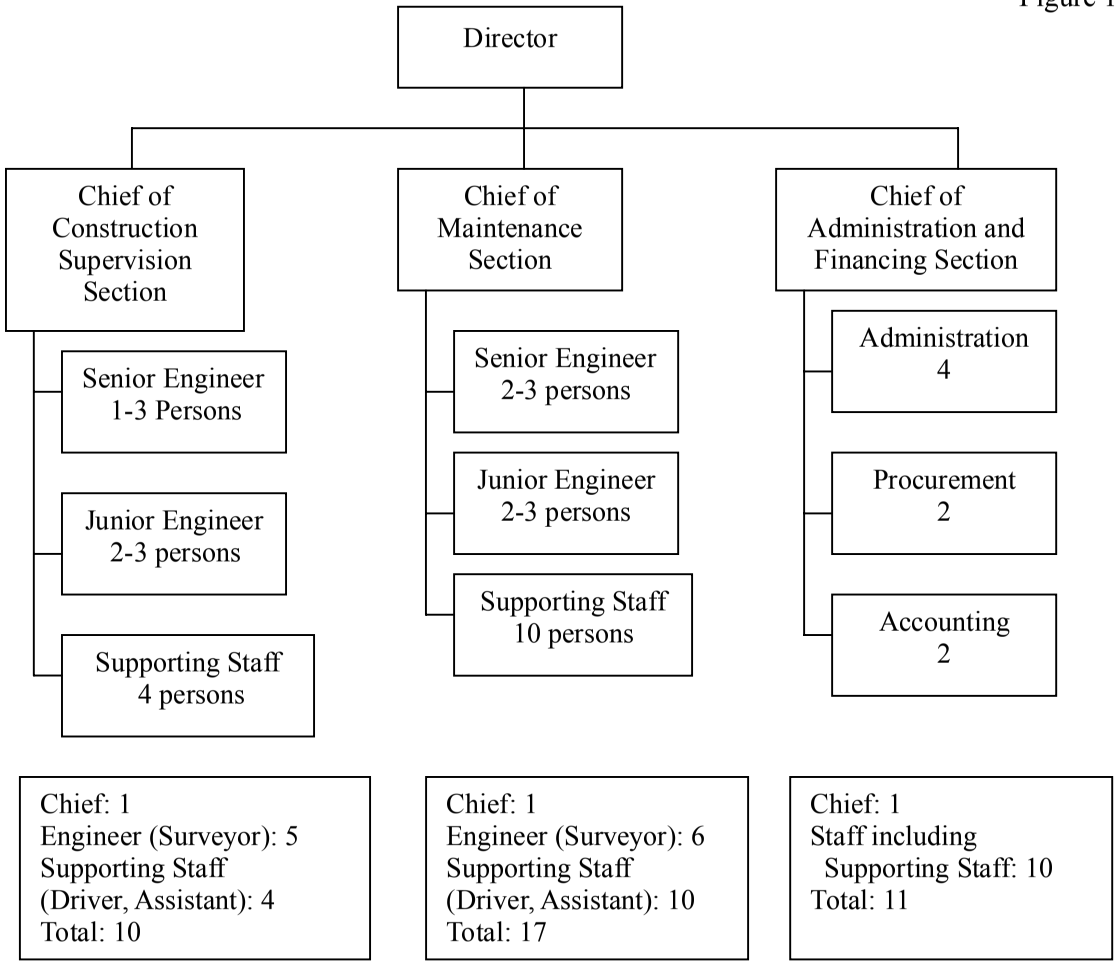


Figure 13.7-7 (a) Proposed DGR Organization
(Medium Term: 2011-2020)

Figure 13.7-7 (b) Proposed DGR Organization
(Medium Term: 2011-2020)
Regional Department (Typical)



Variation in Staff Size

Region	No of Staff	No of Engineer
Batiinah & Musandam	60	30
Dakhliyah & Al Wusta	55	25
Dhahirah	30	15
Sharqiyah	25	10
Total	170	80

13.7.4 Staffing and Recruiting Plan

The number of entire staff and engineers including surveyors for each plan are summarized in Table 13.7-6.

Table 13.7-6 Number of Entire Staff and Engineers (persons)

Plan	Total of Engineer + Surveyor	Others	Total DGR	Annual Increase of Engirees
(Present)	66 (includeing DG & Foreign Experts)	164	230	-
Urgent Action Plan	83	(170)**	253	-
[Increase/Decrease]*	17	-**	23	5.7
Short Term Plan	93	(168)**	261	
[Increase/Decrease]*	11	-**	12	3.7
Med. Term Plan	120	188	308	
[Increase/Decrease]*	27	20	47	2.7
Long Term Plan	150	192	342	
[Increase/Decrease*	30	4		3
Long Term – Present	84			3.4

* [Increase/Decrease]: Increase/decrease from the previous plan

** The number of "Others" should decrease. Decrease of "Others" should be attained by transferring supporting staff from unskilled works to assistant works to engineers or skilled staff after proper training.

As it is seen in the table, average annual increase of engineers/surveyors over 25 years from year 2005 to 2030 is 3.4 persons, without counting those who will retire. Accordingly, at least 3.5 persons of engineers/surveyors need to be newly recruited every year starting from year 2005. In early stage (2005 – 2007) it is necessary to recruit 5 to 6 engineers/surveyor every year to fill the vacancy of new recruitment after year 2001.

Figure 13.7-8 shows the distribution of number of DGR staff by age. Official retirement age of governmental employee is 60. Accordingly, substantial number of present DGR staff is scheduled to retire in the future. Figure 13.7-9 shows the number of DGR staff scheduled to retire in 5-Year Plan periods. The total number of retirement in 25 years is estimated to be 164 persons.

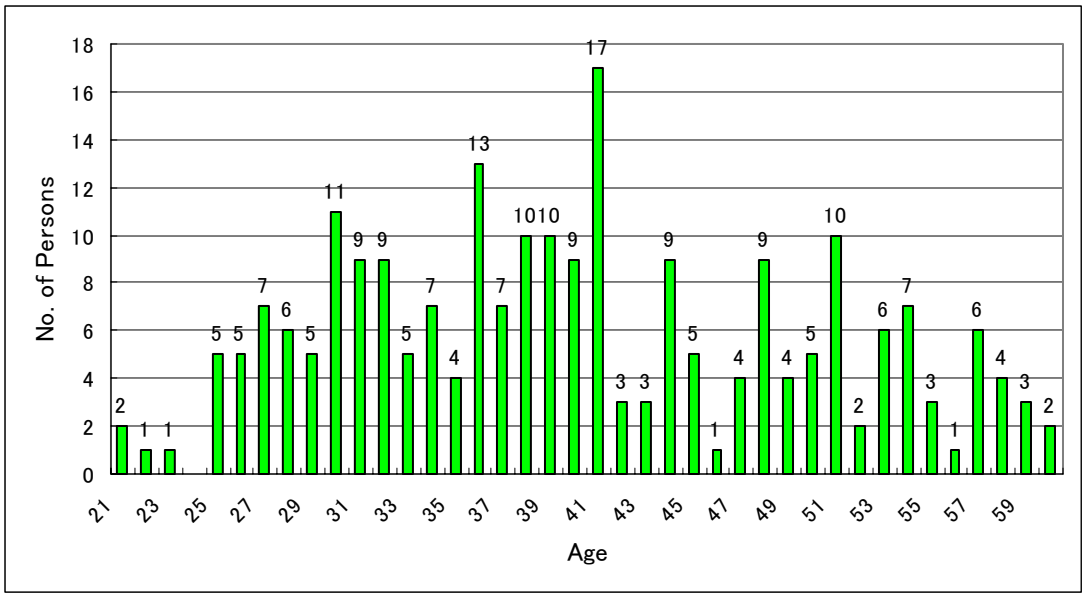


Figure 13.7-8 Distribution of Number of DGR Staff by Age.

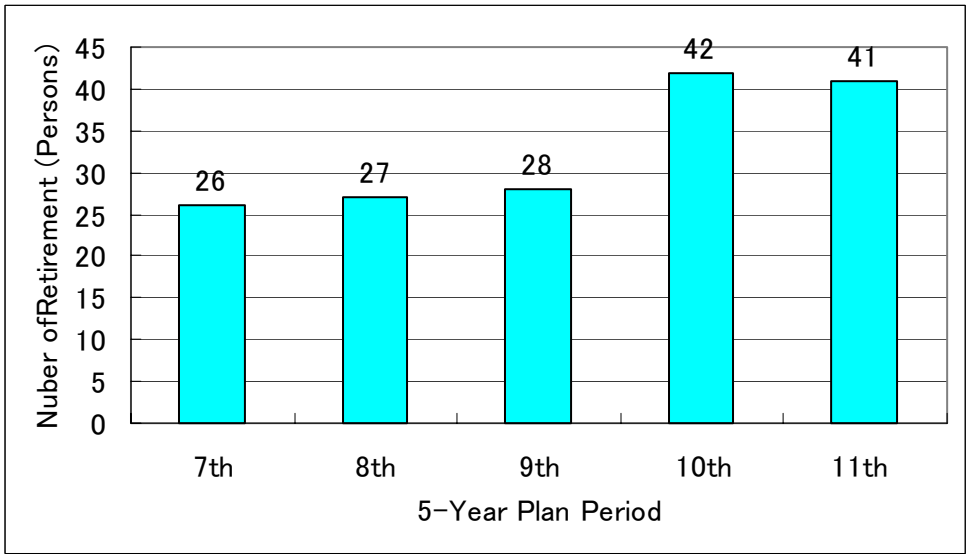


Figure 13.7-9 Number of DGR Staff Retiring in Each 5-Year Plan Period

It is not clear that how many persons are engineers or surveyors among those who will retire. As shown in Table 13.7-1, the percentage of engineers and surveyors in the entire DGR staff is about 30 %. Accordingly, among 164 persons who will retire in the next 25 years, about 50 persons are assumed to be engineers or surveyors. This means 2 persons of engineers/surveyors per year on average will retire. To fill the vacancies of these retiring engineers/surveyors, it is necessary to recruit the same number of engineers or surveyors every year in addition to those shown in Table 13.7-6. **Therefore, 5 to 6 persons of engineers and/or surveyors should be newly recruited every year starting from year 2005.**

13.7.5 Organization Plan of DGC

1) Present Situation

The same discussions made on the organization of DGR can be applied on the organization of DGC. In this case, however, the difference of the road lengths maintained by DGR and DGC need to be taken into account. Table 13.7-7 compares the total length of roads under jurisdiction, number of staff, and road length per one person of staff for DGR and DGC.

Table 13.7-7 Comparison of Road Length and Number of Staff of DGR and DGC

	DGR	DGC	Ratio DRR/DGC
Length of Paved Road (SCEL: km)	5,631	1,486	3.79
Track Road (km)	12,375	2,218	5.58
Number of Staff	230	106	2.17
Number of Engineers/Surveyors	66	12	5.5
Paved Road Length (SCEL)/ No of Staff (km/person)	24.5	14.0	1.75
Paved Road Length / No of Engineer/Surveyor (km/psn)	85.3	123.8	0.69

As it is seen in the above table, the total number of DGC staff is larger than that of DGR with regard to the length of road in the jurisdiction. On the other hand, the number of engineers/surveyors of DGC relative to road length is much less than that of DGR. **Therefore, it is urgently needed for DGC to increase the number of qualified engineers/surveyors.**

2) Number of Staff Required in the Future

In the future, workload of both DGR and DGC is anticipated to increase in the future due to increase in the total length of roads. Table 13.7-8 shows the future road length per one person of staff and per one person of engineers/surveyors. By applying the same road length per person, the number of entire staff and engineers/ surveyors are estimated as shown in Table 13.7-8. The followings can be concluded on the future from the table.

- The total number of staff in the future is same to that of present.
- The number of engineers/surveyors needed in year 2030 is 43 persons compared to 12 persons of today.

Accordingly, 31 persons of engineers/surveyors need to be recruited by year 2030. This means engineers/surveyors need to be increased at an average rate of 1.24 persons per year. Considering the number of staff who will retire, DGC need to recruit about 2 persons of engineers/surveyors every year starting from year 2005.

Table 13.7-8 Number of Staff of DGR and DGC in Future

	DGR	DGC
Length Paved Road for Maintenance in Year 2030 (SCEL: km)	11,860	3,390
No of Total Staff (Person)	342	(98)*
No of Engineer/Surveyor (Person)	150	(43)*
Road Length / Staff	34.7	(34.6)
Road Length / Engineer/Surveyor	79.1	(78.8)

* Estimated by assuming the figures road length per person same to those of DGR