Comparison of Hydraulic Characteristics and Chemical Composition of Groundwater in Monywa Township, Sagaing Region

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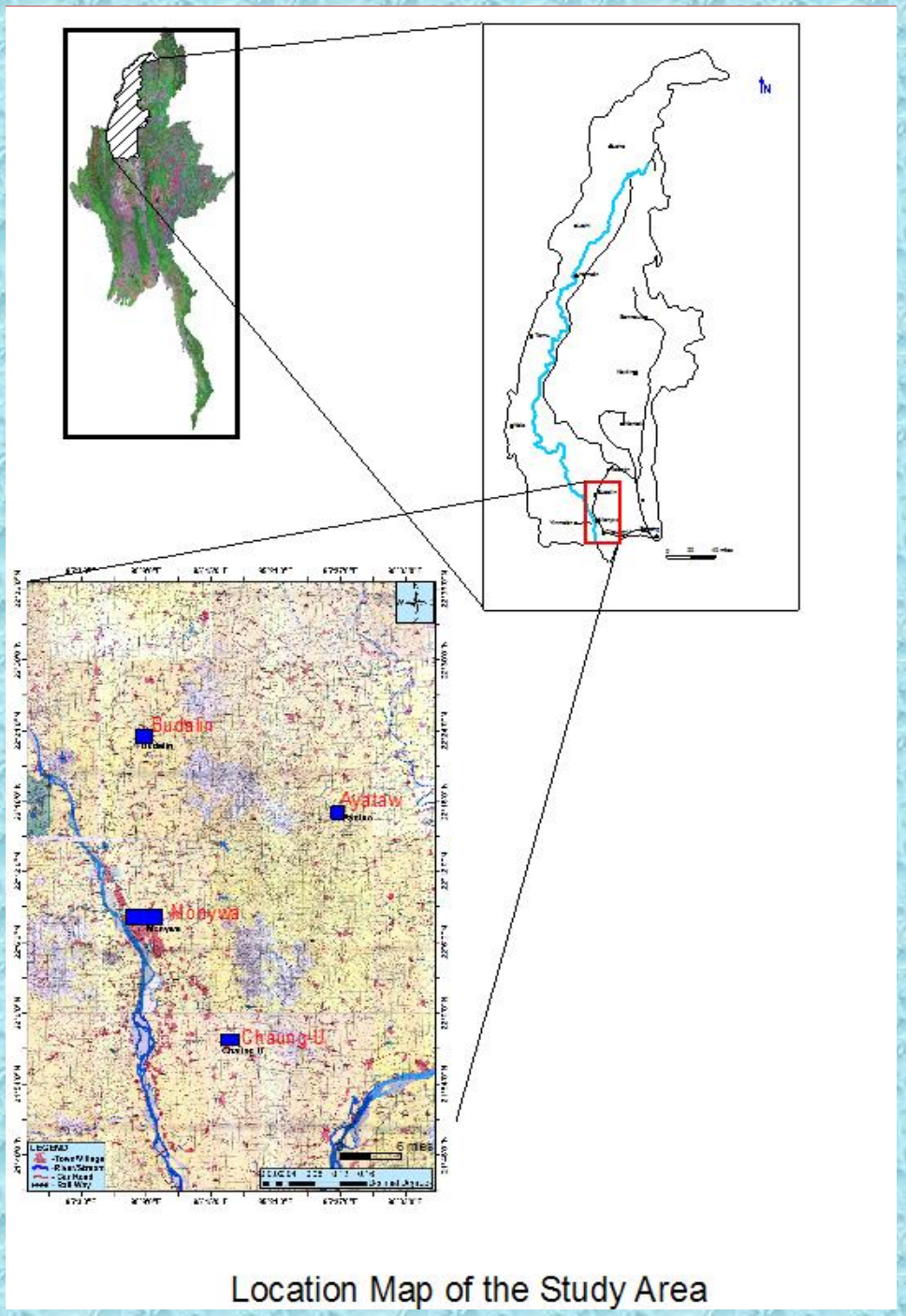
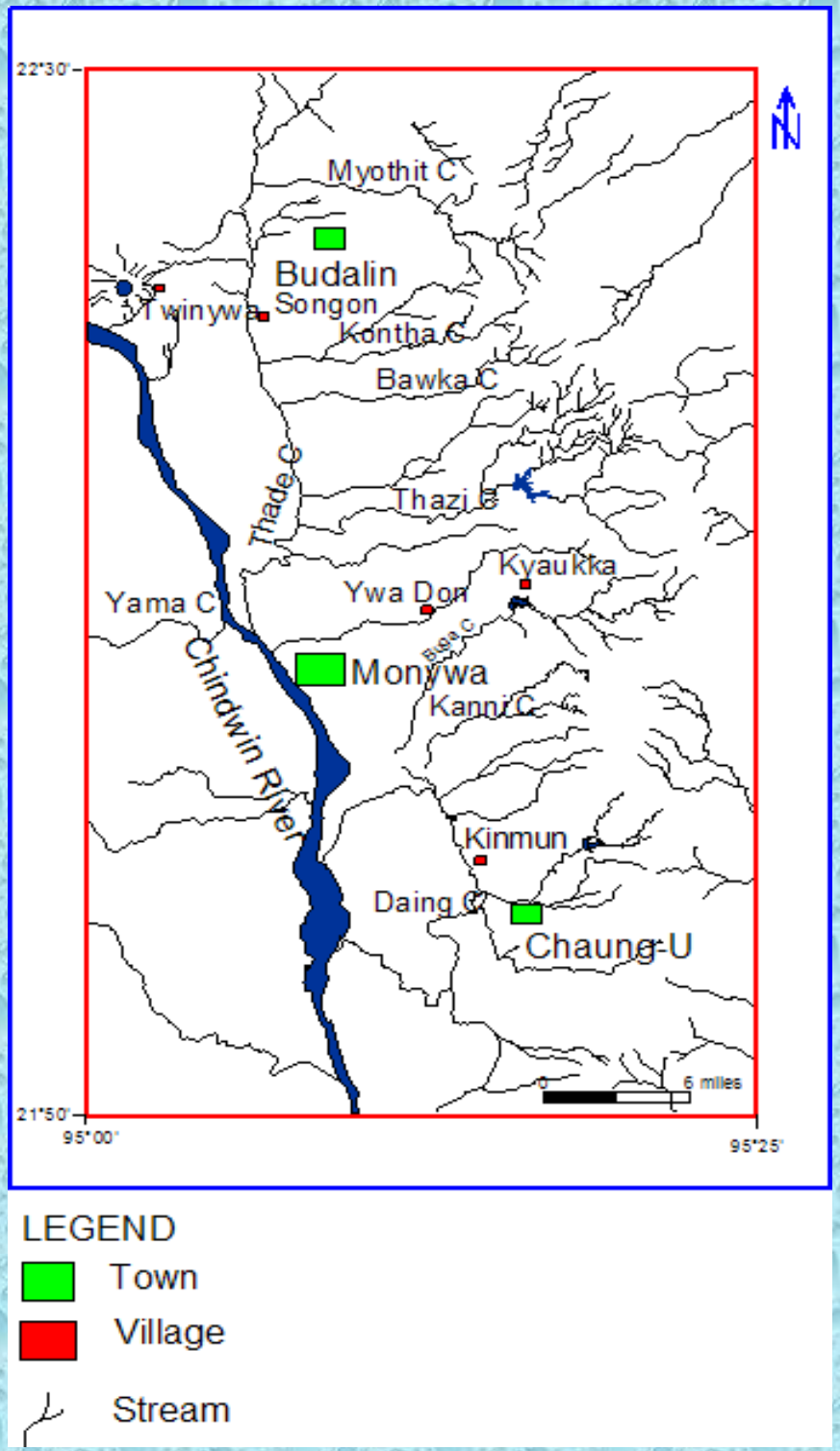
Location Map of the Study Area



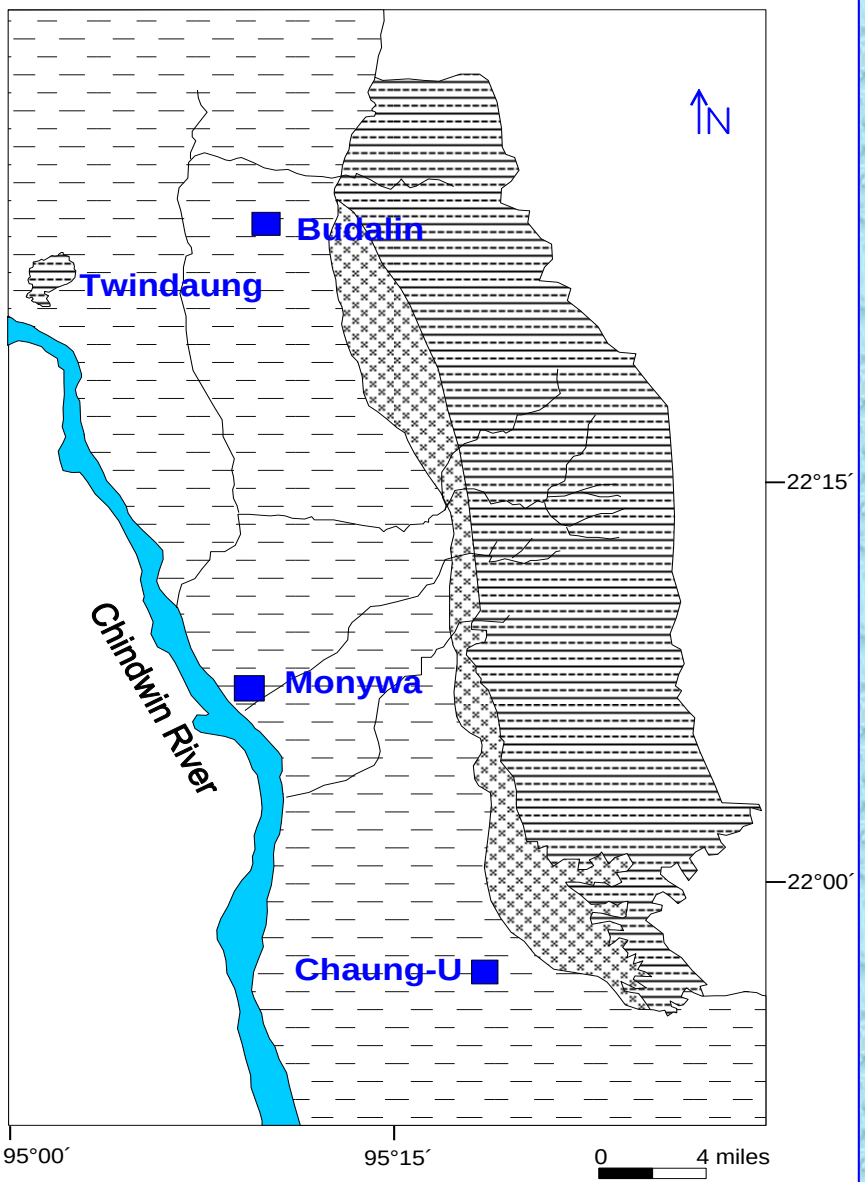
Location Map of the Study Area



Drainage map
of the study area

PHYSIOGRAPHY

- Topography
  - Flat plain
  - Rolling hills
  - Steep hills
- Drainage
  - The Chindwin river flows roughly to the S.S.E direction
  - Most streams in the study area flow into the Chindwin river from east to west



Flat plane (220'-250')

Rolling hills (250'-500')

Steep hills (1000'-1262')

Topographic Map of the Study Area

Climate

- Mean annual rainfall- 25 inches

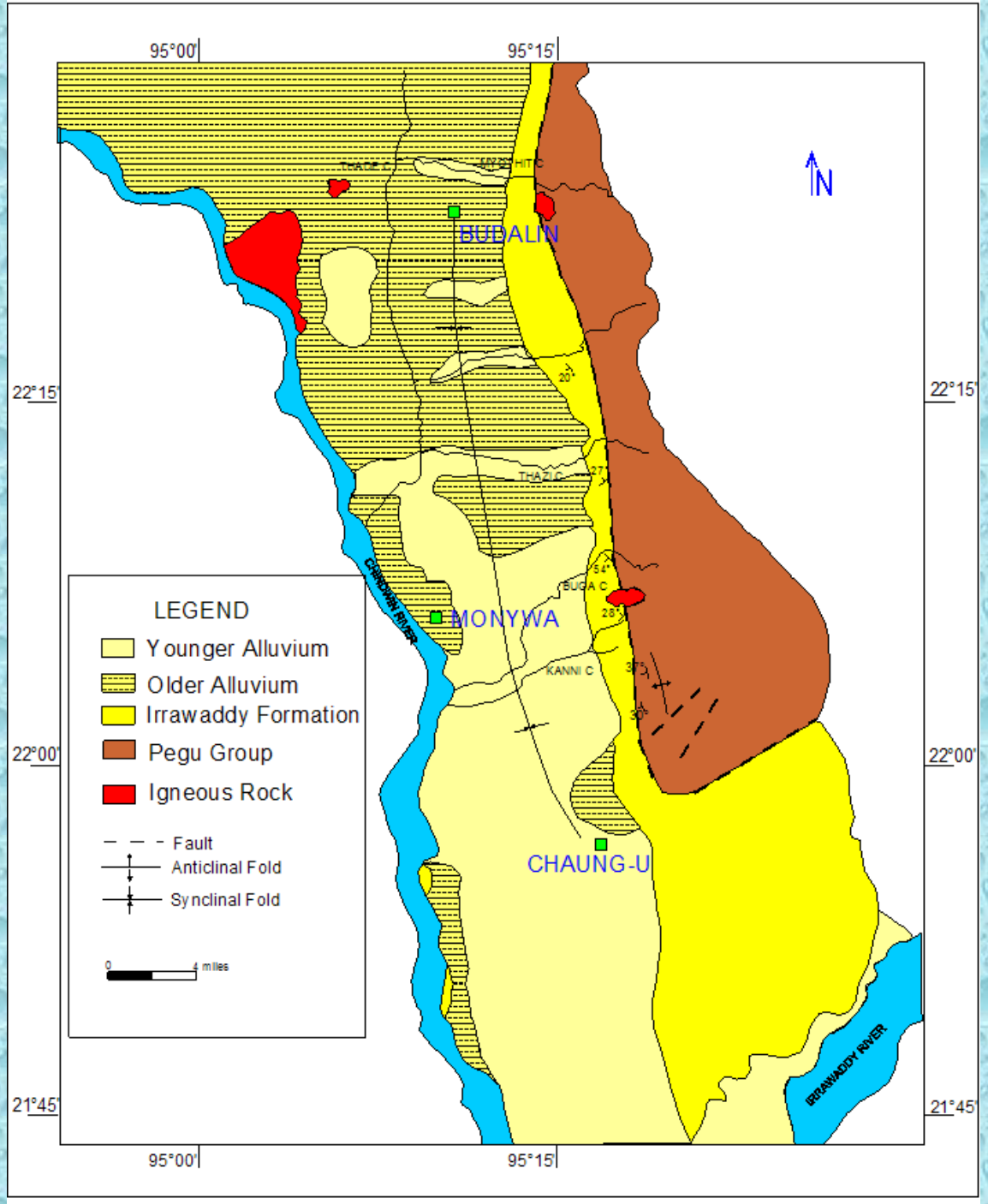
- Temperature -31.5 °C in December
  44.6 °C in April

- Evaporation -2.1” in December
  5.4” in April

GENERAL GEOLOGY

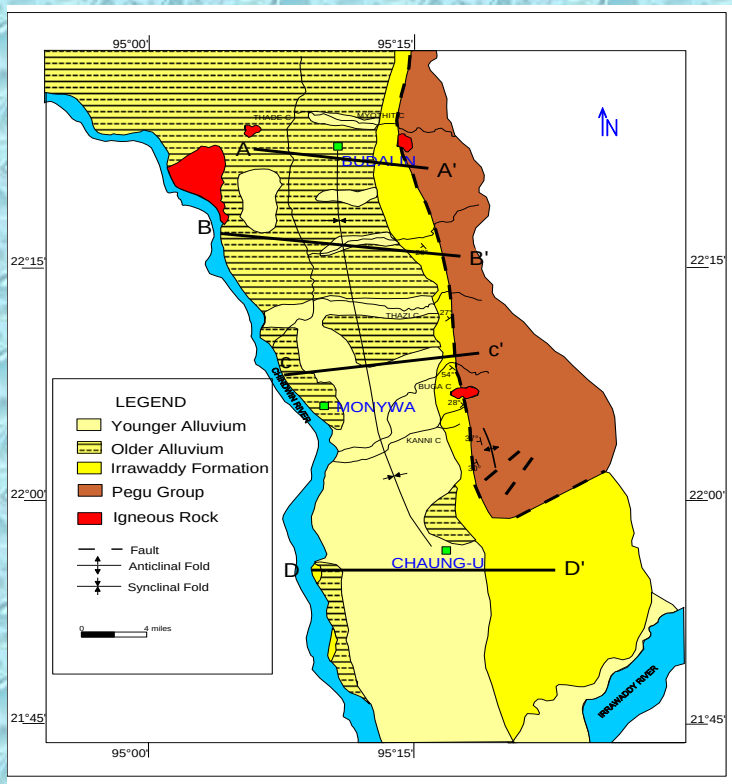
- Stratigraphic Sequence of the Study Area

System	Series	Lithostratigraphic units	Lithology	Hydrological significance
QUATERNARY	Recent	Younger Alluvium	clay, silt, sand and gravel	Aquifer with high yield
	Pleistocene	Older Alluvium	Clay, silt, sand, gravel and plateau gravel	Aquifer with high yield
TERTIARY	Late Miocene to Early Pleistocene	Irrawaddy Formation	Loosely cemented sandstone with minor sandy clay and shale	Aquifer with moderate to high yield
	Oligo-Miocene	Pegu Group	Rapid alternation of shale, siltstone and sandstone	?
Pre - Tertiary		Basement Complex	Diorite, Diabase,Granophyre	-

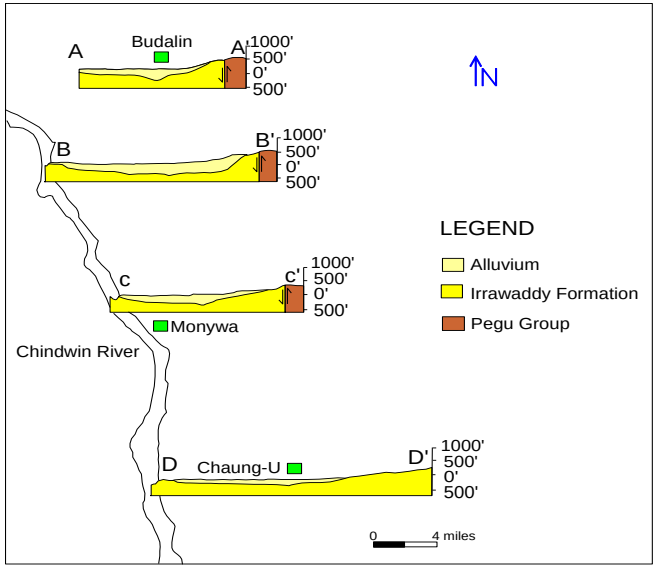


Source from MGS (2014) and U Tun Lwin (1981)

Geological Map of the Study Area



Source from MGS (2014) and U Tun Lwin (1981)



Geological Cross-Section of the Study Area

Geological Cross-Section of the Study Area

Alluvium

- Alluvium can be sub-divided on the basic of their nature of sediments

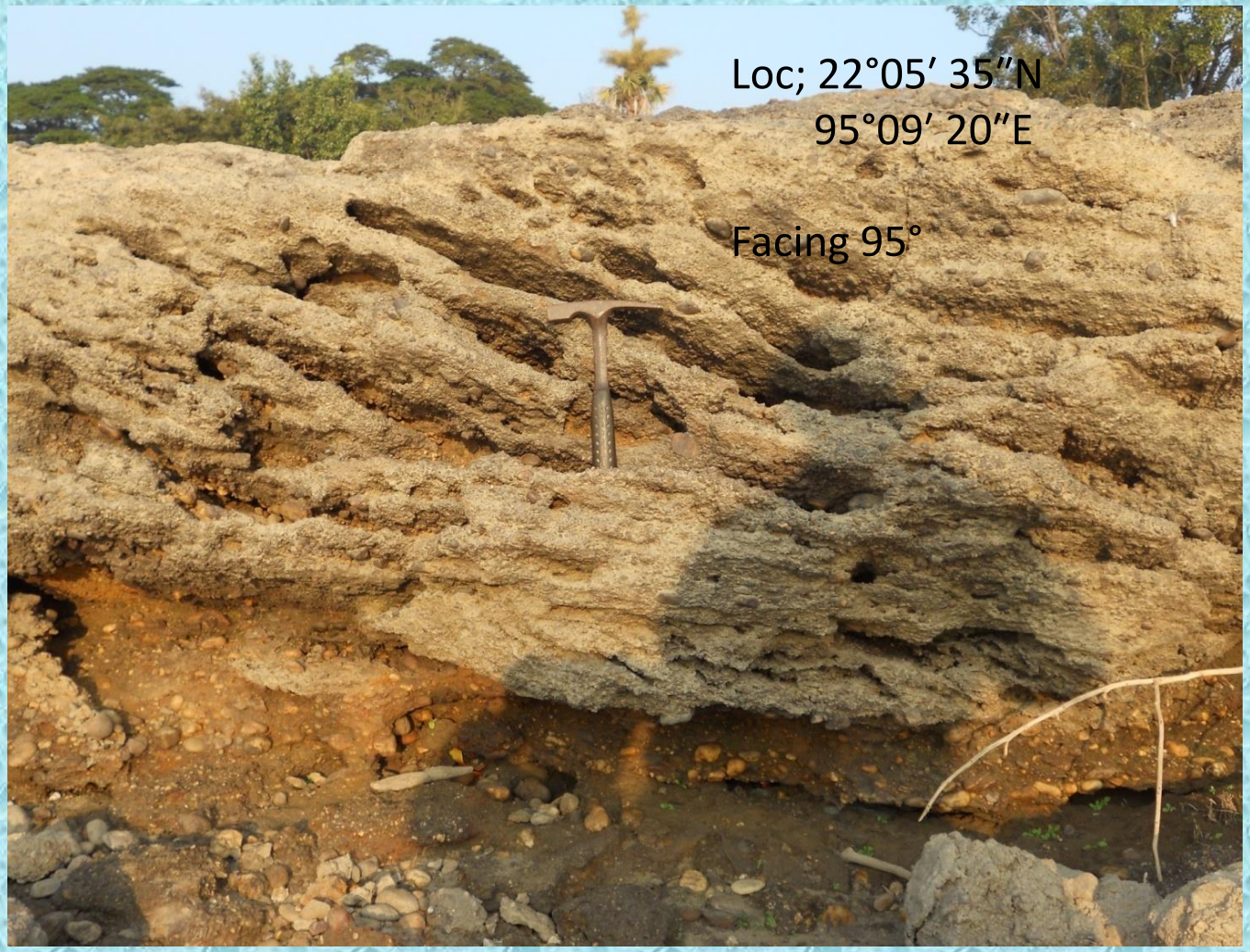
  - Younger Alluvium
  - Older Alluvium

Younger Alluvium

- It is found at the southern part of the study area
- It is mainly composed of silty clay, sandy clay, fine to medium sand with gravel

Older Alluvium

- It is widely distributed at the northern part of the study area
- It is mainly composed of silty clay, clayey sand, medium to coarse sand with gravel and plateau gravel



Pebbly conglomerate along the Chindwin river bank

Irrawaddy Formation

- It is widely distributed at the eastern part of the study area
- It is mainly composed of loosely cemented sandstone with minor sandy clay and shale

Loose sandrock of the Irrawaddy Formation exposed at Nwegwe chaung

Pegu Group

- It is widely exposed at the eastern part of the study area
- It consists of rapid alternation of shale, siltstone and sandstone

Sand and shale alternation of the Pegu Group exposed at Bawditahtaung Dam

Igneous rocks

- It is widely exposed at the north western part of the study area ,especially in Twintaung area

GEOLOGICAL STRUCTURE

- Regional Dips and Folds

  Dip amounts - varies from 13 to 25 degree and at some places, reach 45˚ or 50˚

  Dip direction - generally to the west

  Anticlinal fold- Kyaukka-Inde hill range

  Synclinal fold- Monywa-Chaung-U Basin

- Fault

  Kyaukka fault

Hydrogeology of the Study Area

- **Chemical Characteristics of Groundwater**
- **Hydraulic Characteristics of Aquifer**

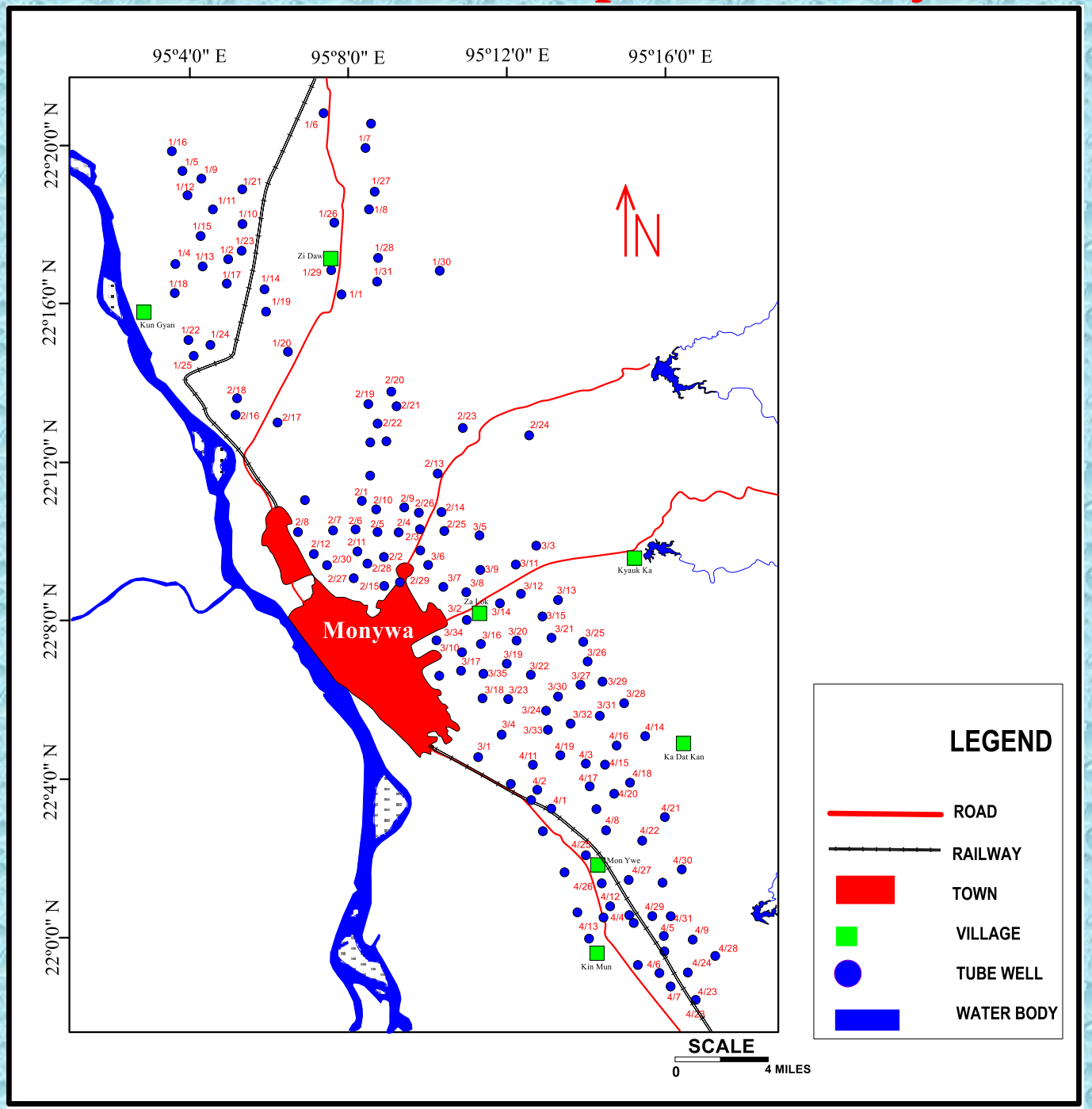
Chemical Analysis and Evaluation of Groundwater Quality

- Chemical data of tube wells were collected from W.R.U.D.
- Major cations and anions were analysed

  Cations: Ca^{+2}, Mg^{+2}, Na^{+1}, $K^{+1}$and Fe^{+2}

  Anions: HCO_3^{-1}, $SO4^{-2}$,Cl^{-1} and CO_3^{-2}
- pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS) were also analyzed.

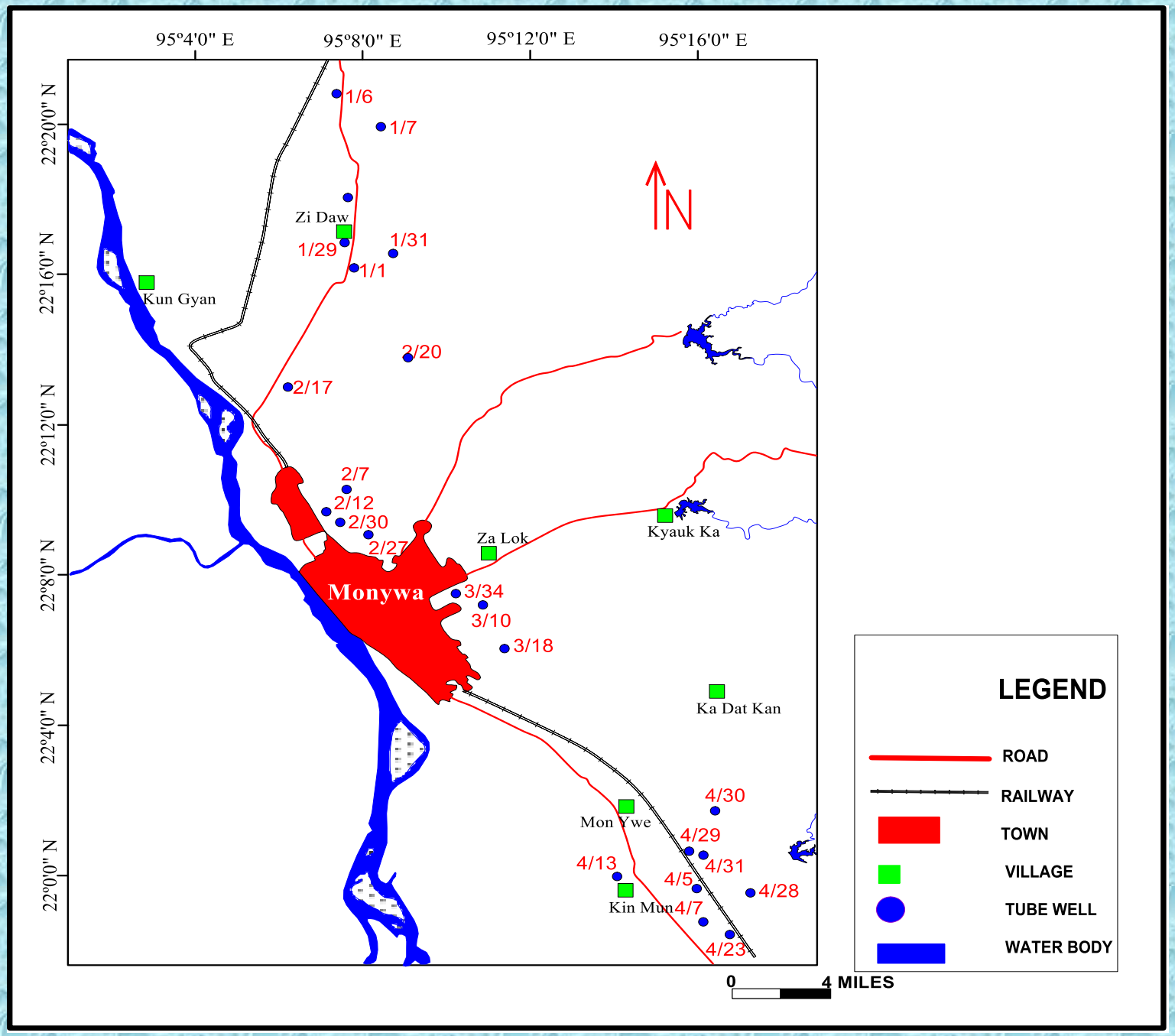
Tube wells location map of the study area



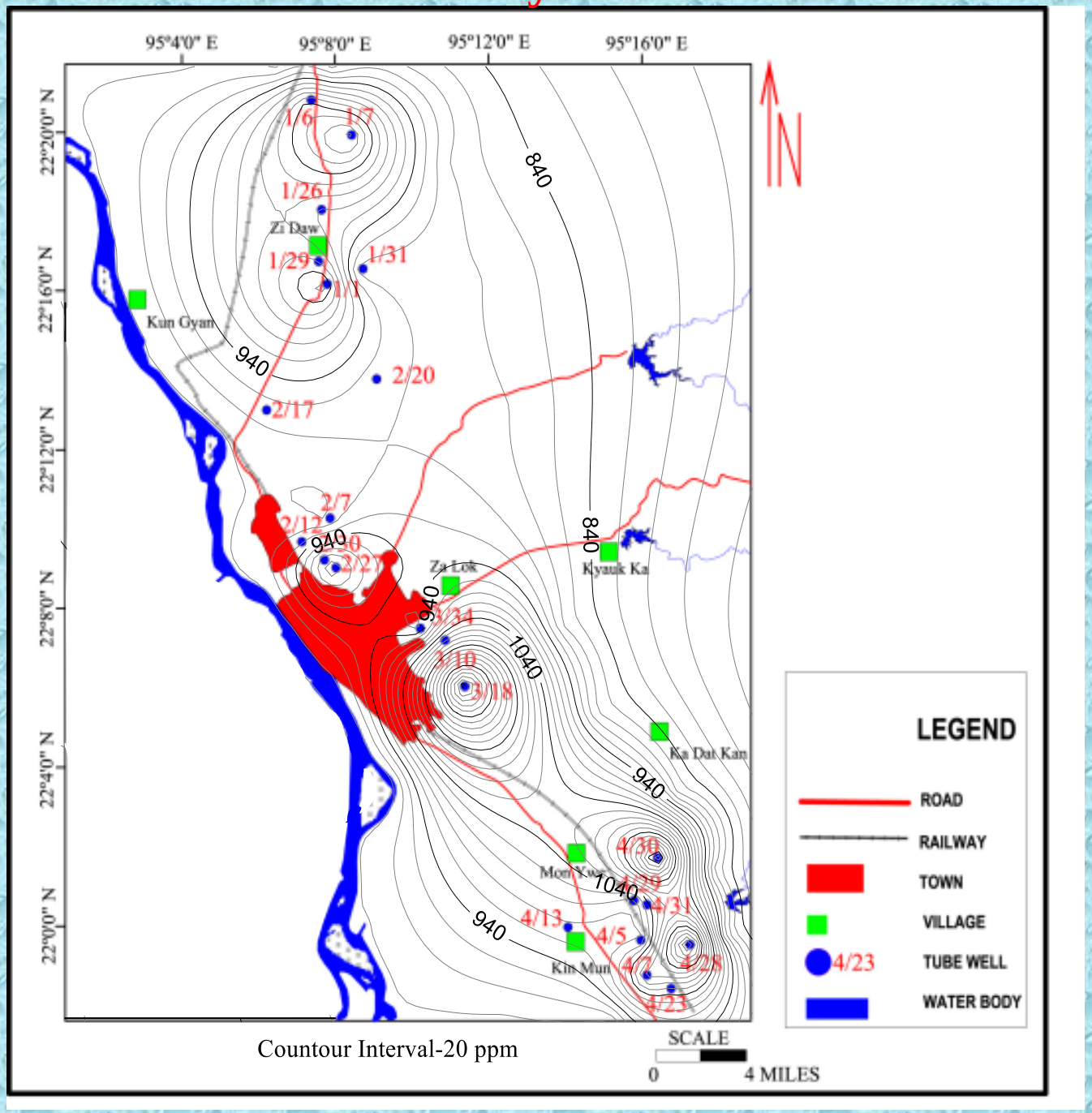
Method of Analysis

- Chadha Diagram (Proposed Diagram) is used to classify the type of groundwater
- Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Permeability Index (PI), Residual Sodium Bicarbonate (RSBC), Soluble Sodium Percentage (SSP) and Kelly's ratio (KR) were assessed and compared with standard limits for quality of irrigation water

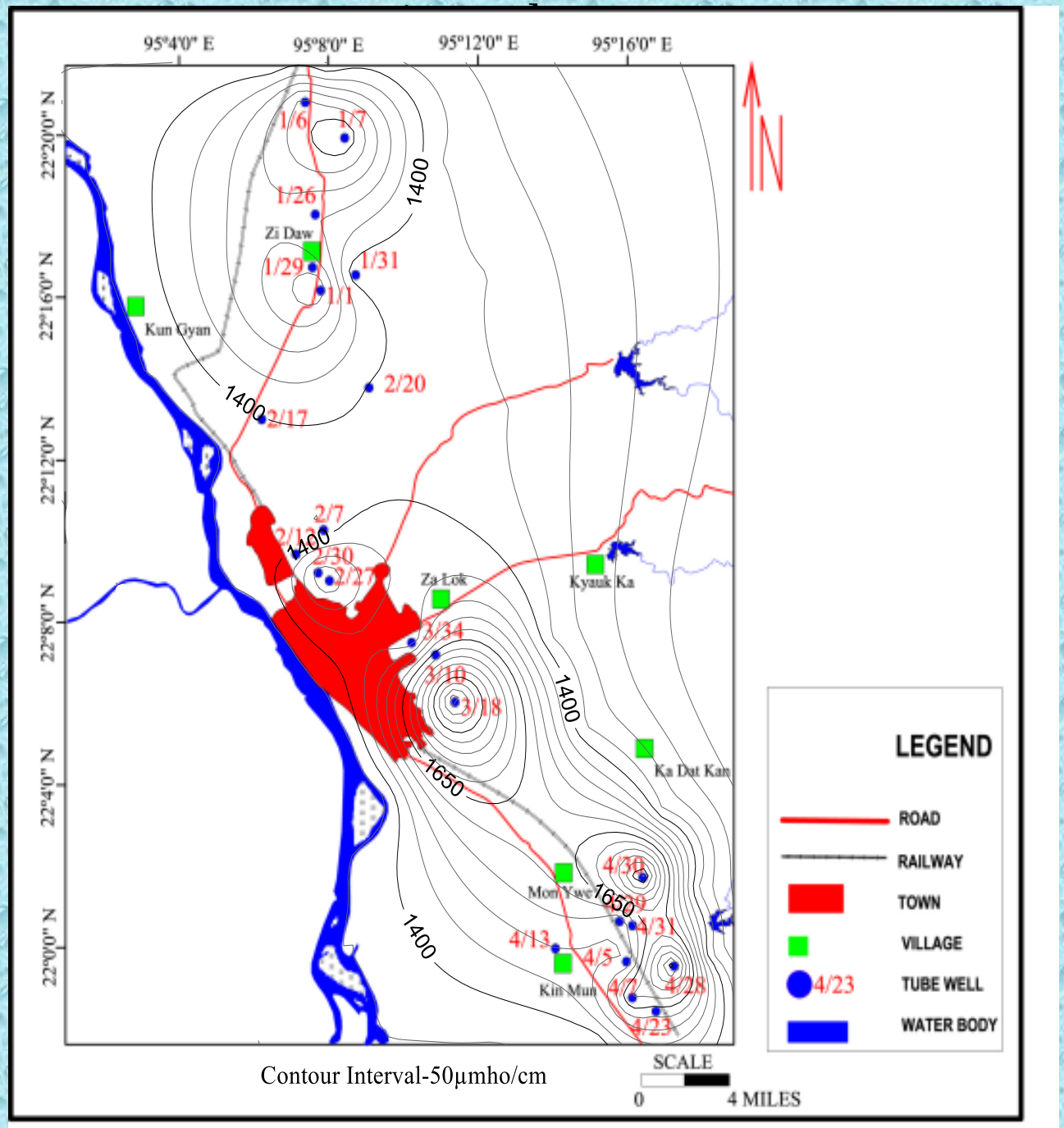
Tube wells location map of the Younger Alluvial Aquifer



Distribution of Total Dissolved Solid in water of Younger Alluvial Aquifer in study area



Distribution of Specific Electrical conductance in water of Younger Alluvial Aquifer



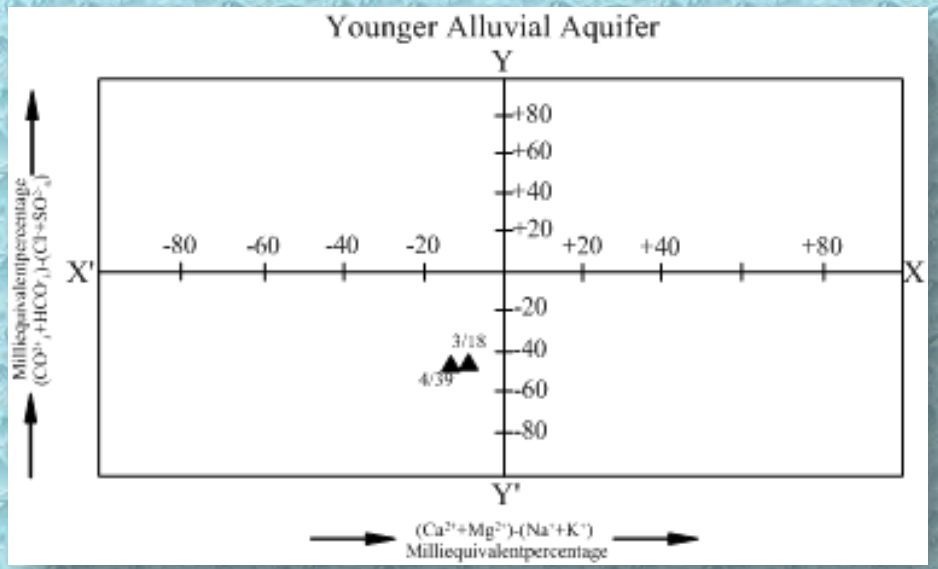
Chemical Analysis Data of Groundwater from Younger Alluvial Aquifer

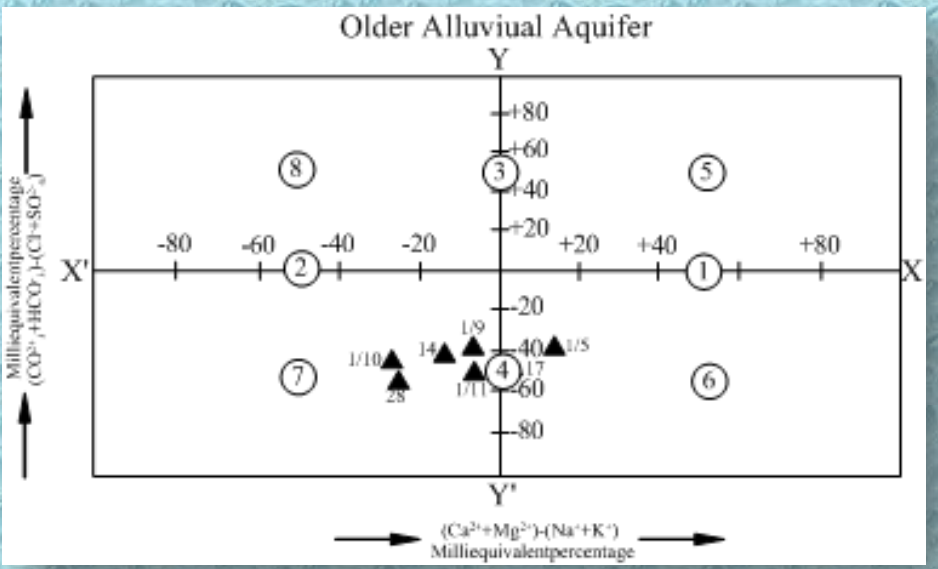
Sr, No	Well No	TDS	EC	pH	Total Hardness	Concetration of ions in milligram per litre								
						Fe (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	CL (mg/l)
1	BDL-1/1	1072	1650	6.76	290	2.5	136	10	56.24	35.88	ND	244	107.64	183
2	BDL-1/6	1046	1610	6.7	272	2.5	123	5	71.46	22.44	ND	148	67.32	169
3	BDL-1/7	1111	1710	6.85	280	3	132	5	74.35	22.68	ND	148	68.04	163
4	BDL-1/26	975	1500	6.77	204	3	123	5	58.24	14.14	ND	132	42.42	199
5	BDL-1/29	1027	1580	6.87	208	2.5	174	4	56.37	16.2	ND	138	98.60	148
6	BDL-1/31	890	1370	6.55	154	25	114		31.82	16.08	ND	110	98.24	165
7	MY-2/7	877	1350	7.72	210	2.5	138	3.4	48.3	21.48	ND	130	164.44	188
8	MY-2/12	910	1400	6.88	252	2.5	135	3.12	57.4	26.04	ND	120	78.12	170
9	MY-2/17	910	1400	6.78	364	2.5	126	4.3	95.76	30	ND	140	90	153
10	MY-2/20	910	1400	6.68	284	2.5	167	3.3	51.3	37.44	ND	120	112.32	134
11	MY-2/27	1040	1600	7.77	242	2.5	110	2.1	53.44	26.04	ND	136	178.12	260
12	MY-2/30	1007	1550	7.76	240	2.5	140	2.1	44.8	30.72	ND	136	192.16	210
13	MY-3/10	1066	1640	6.22	420	6	144	6.1	80.96	52.32	ND	190	156.96	432
14	MY-3/18	1365	2100	6.7	290	2	158	6.3	60.28	33.48	ND	100	200.44	183
15	MY-3/34	910	1400	6.67	382	3	79	5	94.18	35.28	ND	126	187.84	283
16	CU-4/5	975	1500	7.66	264	2.5	120	10	43.82	37.08	ND	140	111.24	220
17	CU-4/7	1111	1710	6.76	260	2.5	145	14	47.8	33.72	ND	150	101.16	184
18	CU-4/13	975	1500	6.76	324	3	130	12	79.24	30.24	ND	122	90.72	160
19	CU-4/23	1053	1620	6.66	308	2.5	134	12	64.77	35.16	ND	140	105.48	277
20	CU-4/28	1261	1940	7.57	464	3	162	17	114.8	42.84	ND	128	127.44	184
21	CU-4/36	1287	1980	6.88	358	3	96	8	69.24	44.4	ND	118	133.2	272
22	CU-4/39	988	1520	6.8	264	2.5	95	6	56.43	29.52	ND	168	88.56	208

Comparison with Groundwater in the Study Area and WHO Drinking Water Quality Standard, 2011 and FAO Guideline standard

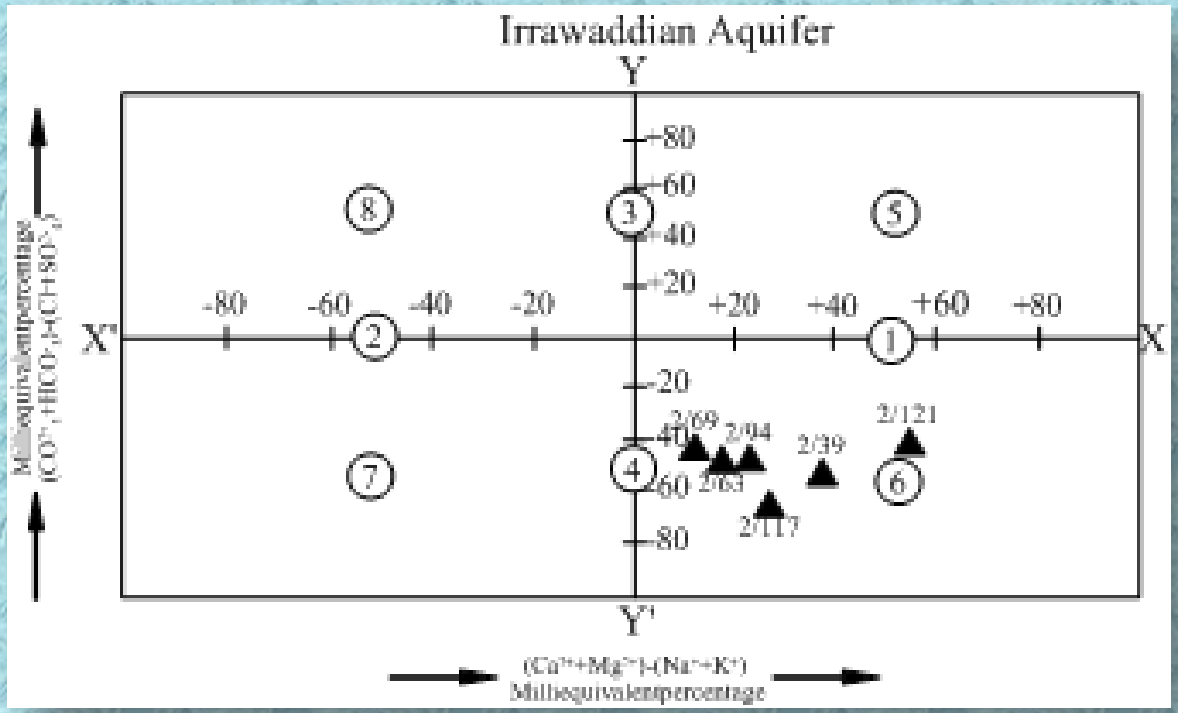
Characteristics	Guideline Value WHO		Guideline value FAO	The range obtained value from ground water	Remarks
	Desirable	Max Permissible			
Calcium	75 mg/L	200 mg/L	800mg/L	31.82-123.5mg/L	Good
Magnesium	30 mg/L	150 mg/L	120mg/L	16.08-52.32 mg/L	Good
Sodium	- mg/L	200 mg/L	920mg/L	79-174 mg/L	Good
Potassium	- mg/L	-	2mg/L	4-17 mg/L	-
Sulphate	- mg/L	250 mg/L	960mg/L	67.32-200.44 mg/L	Good
Chloride	200 mg/L	250 mg/L	1065mg/L	134-432 mg/L	Good,Except wells 11,13,15,19,21
Iron	0.3mg/L	1mg/L	5mg/L	2-6mg/L	Almost wells are above 1 mg/L
TDS	- mg/L	1000 mg/L	2000mg/L	877-1365 mg/L	Good,Except wells 1,2,3,5,11,12,13,14,17,19,20,21
pH	6.5	8.5	6.5-8.5	6.22-7.77	Good
Hardness $CaCO_3$	- mg/L	500 mg/L		154-464 mg/L	-
EC	- Micromho /cm	1500 Micormhos /cm	3000 micromho /cm	1350-2100 Micromhos /cm	Good ,Except wells 1,2,3,5,11,12,13,14,17,19,20,21, 22

Chadha Diagram (Proposed Diagram)





Such water generally creates salinity problems both in irrigation and drinking uses.



Such water has permanent hardness and does not deposit residual sodium carbonate in irrigation use.

Assessment of Groundwater Quality for Irrigation Purposes

- **Sodium Adsorption Ratio (S.A.R)**
- **Soluble Sodium Percentage (S.S.P)**
- **Residual Sodium Bicarbonate (R.S.B.C)**
- **Magnesium Adsorption Ratio(M.A.R)**
- **Kelly's Ratio (K.R)**
- **Permeability Index (P.I)**

Sodium Adsorption Ratio (SAR)

- SAR was calculated by the following equation given by Richards (1954) as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$, all the ions are express in meq/l

SAR value range in study area 1.76 to 5.25.

A high percentage of Na in water, the soil becomes more plastic and this will restrict water movement.

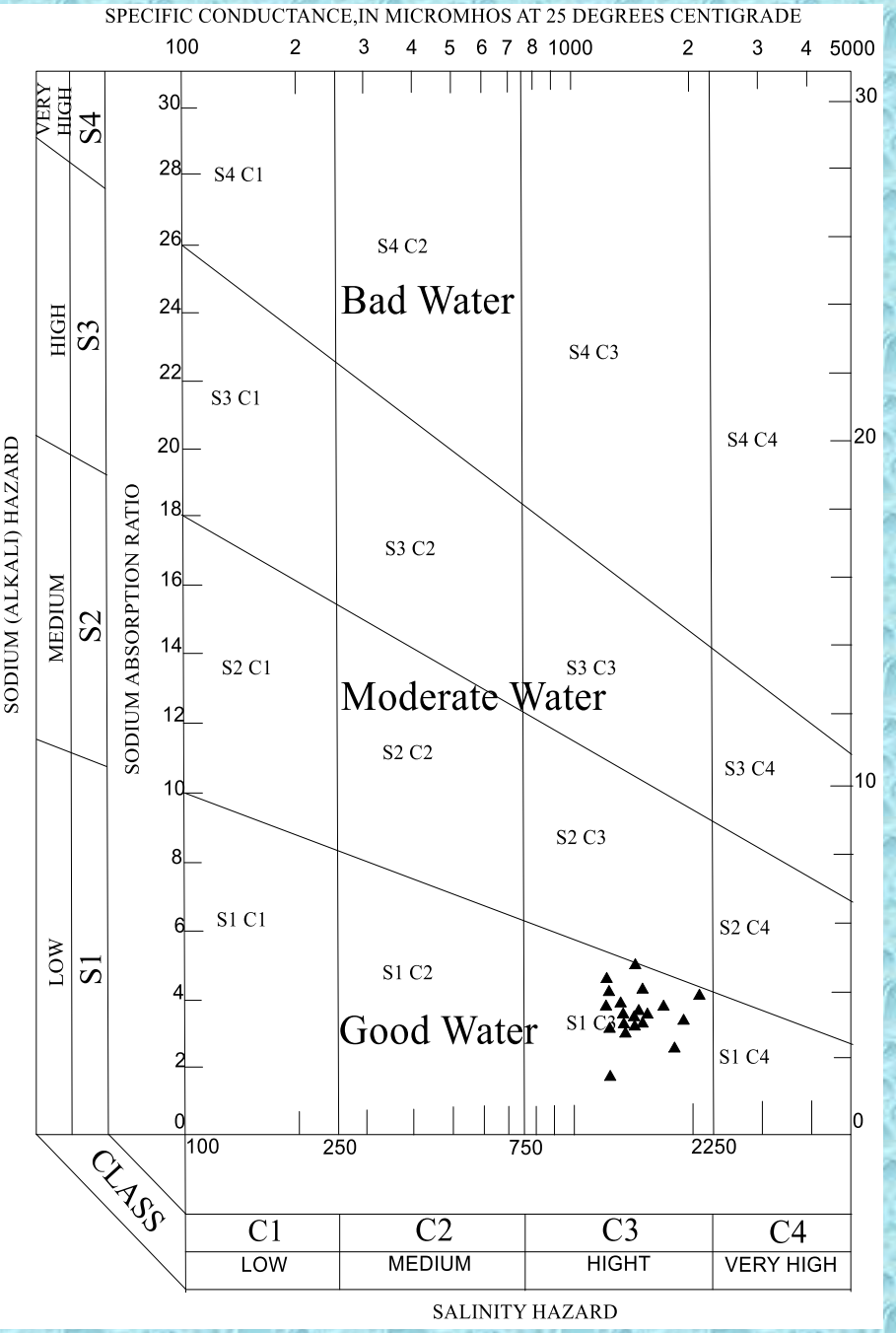
Water Class	SAR
Excellent	up to 10
Good	10 - 18
Medium	18 – 26
Bad	> 26

Salinity Hazard

In the study area, almost the water falls in the S1 C3 type .

S1 C3 means Low Sodium water with high Salinity Hazard.

USDA(after- Richards)



Soluble Sodium Percentage (SSP or Na%)

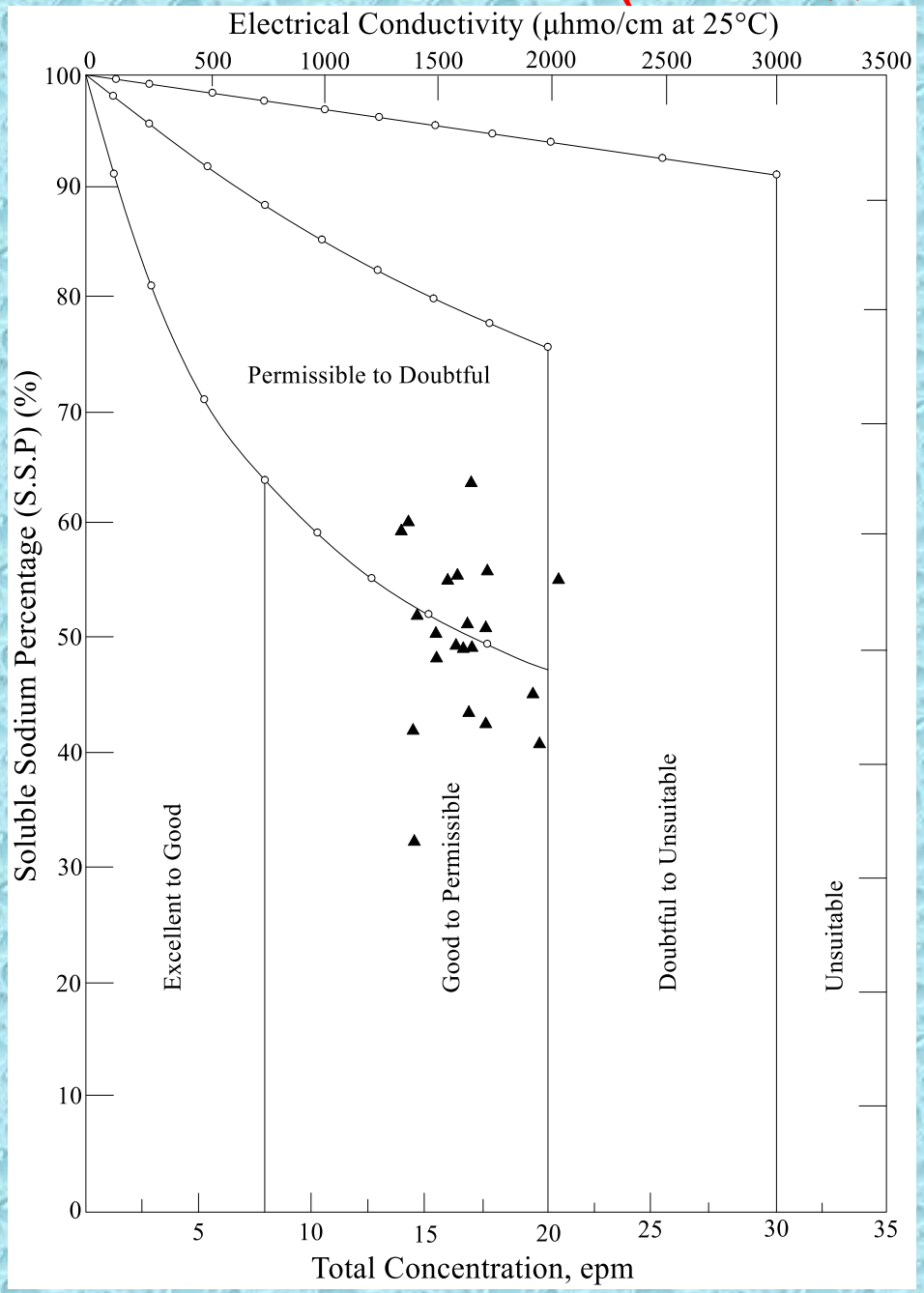
- Water with SSP greater than 60 percent may result in sodium accumulation that will cause a breakdown of the soils physical properties.
- When the concentration of sodium ions is high in irrigation water, Na^+ ions tends to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. (after, F.M.Eaton,1950).
- This exchange process reduces the permeability of the soil and internal drainage .(SSP value range in study area is 30.73 to 64%)

$$SSP = \frac{(Na^+ + K^+)}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

ions are express in meq/L

Water Class	SSP%
Excellent	< 20
Good	20 - 40
Fair	40 – 80
Poor	> 80

Classification of groundwater for Irrigation Base on Na% (After Wilcox, 1955)



- 12 samples are Good to permissible limit, 8 samples are permissible to doubtful and one sample is unsuitable

Residual Sodium Bicarbonate (RSBC)

- The concentration of bicarbonate and carbonate influences the suitability of water for irrigation.
- Water with high RSBC has high pH , and calculated by the following:

$$RSBC = HCO_3^- - Ca^{2+}$$

- Land irrigated with such water becomes infertile owing to deposition of sodium carbonate (Eaton, 1950).
- The residual sodium bicarbonate values of water samples from the study area vary from -3.63 to 0.1 meq/l.
- Maximum permissible of the RSBC is 2.5.

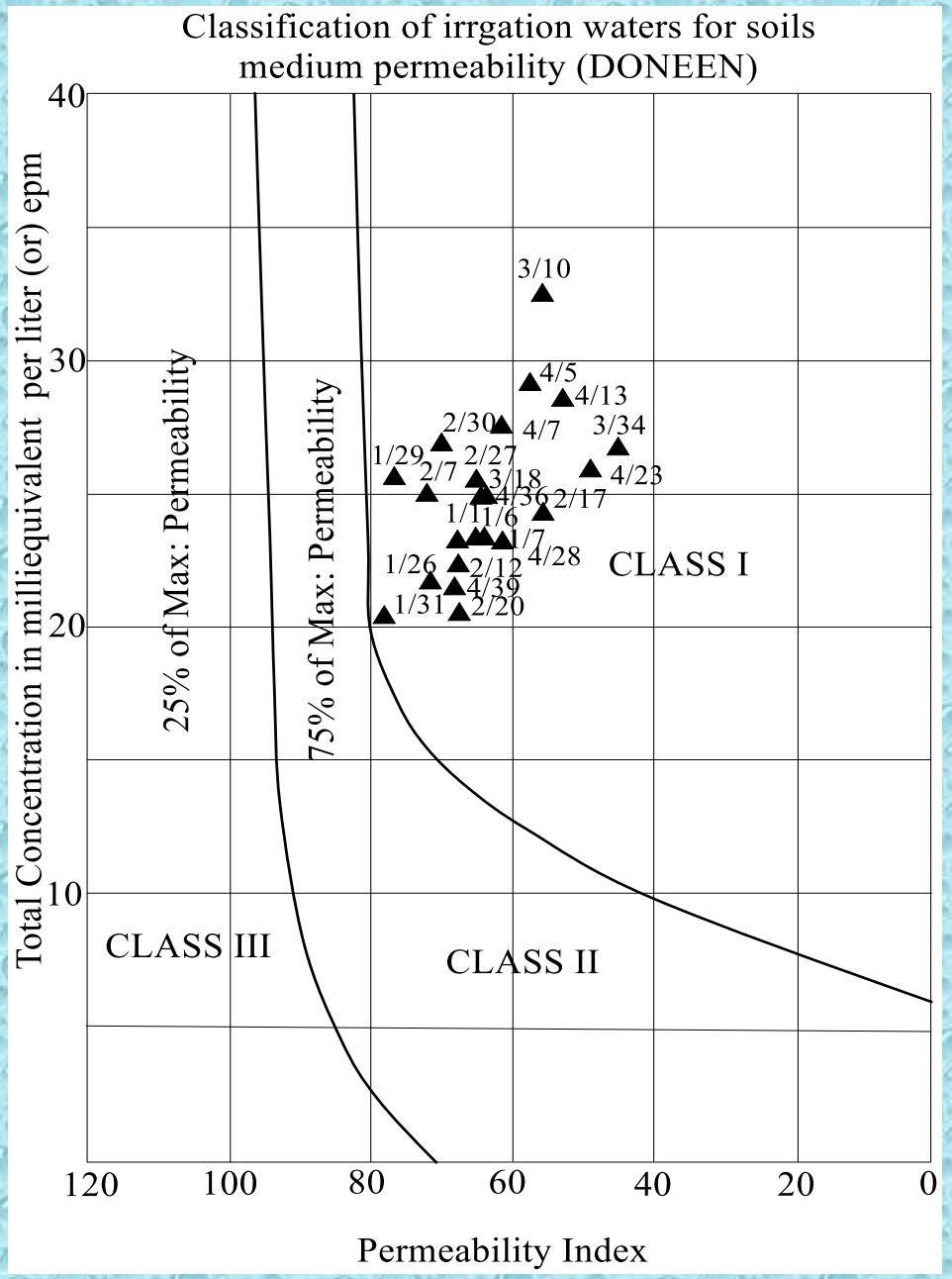
Permeability Index (PI)

- The soil permeability is affected by the long-term use of irrigated water
- The influencing constituents are the total dissolved solids, sodium, bicarbonate and the soil type
- The permeability Index (PI) was calculated according to Doneen (1964) employing the following equitation:

$$\mathrm{PI} = \frac{Na^{+} + \sqrt{\mathrm{HCO_3}^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100$$

- In the present study, the permeability index values range between (44% to 78%).

Possible Utilization of Groundwater for Irrigation by Permeability Index (Doneen)



Most of the groundwater samples fall under Class I
Class I is suitable for Irrigation

Magnesium Adsorption Ratio (MAR)

- MAR is considered as one of the most important qualitative criteria in determining the quality of water for irrigation
- More magnesium of in water will adversely affect crop yields as the soil become more saline (Joshi et al., 2009)
- MAR was calculated using the following equation (Raghunath, 1987)

$$\text{MAR} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100$$

- High magnesium adsorption ratio causes a harmful effect to soil when it exceeds 50%
- In the study area M.A.R value range (28.5 to 58.2%).

Kelly's Ratio (KR)

- These indicate that most of the KR for the groundwater samples however fall within the permissible limit of 1.0 and considered suitable for irrigation purposes.
- The Kellys Ratio was calculated employing the following equation. (after, Kelly,W.P 1963).

$$KR = \frac{Na}{Ca+Mg}$$

- In the study area KR value range(0.4 to 1.6).

Allowable Unit		
Parameter	Minimum	Maximum
SSP (%)	<20	80
RSBC (meq/L)	1.25	2.5
MAR (%)	7.97	50
KR	0	1
SAR	<10	>26

Assessment of Groundwater quality for Younger Alluvial Aquifer

Sr, No	Well No	TDS	EC	MAR	RSBC	KR	SAR	SSP	PI	Remark
1	1/1	1072	1650	51	1.2	1.0	3.49	49.5	68	Unsuitable
2	1/6	1046	1610	34	-0.7	1.0	3.25	49.1	64	Suitable
3	1/7	1111	1710	34	-0.2	1.0	3.44	50.1	64	Suitable
4	1/26	975	1500	29	-0.8	1.3	3.75	56.0	72	Unsuitable
5	1/29	1027	1580	32	-3.1	1.8	5.25	64.1	77	Unsuitable
6	1/31	890	1370	43	-1.1	1.6	4.01	60.7	78	Unsuitable
7	2/7	877	1350	42	-1.3	1.4	4.15	58.4	73	Unuitable
8	2/12	910	1400	43	-1.0	1.2	3.71	53.6	67	Unsuitable
9	2/17	910	1400	34	-2.0	0.8	2.88	42.7	55	Suitable
10	2/20	910	1400	55	-0.9	1.3	4.32	55.9	68	Unsuitable
11	2/27	1040	1600	44	-1.4	1.0	3.08	49.6	65	Suitable
12	2/30	1007	1550	53	-1.1	1.3	3.94	55.5	70	Unsuitable
13	3/10	1066	1640	52	-1.1	0.8	3.07	42.4	55	Unsuitable
14	3/18	1365	2100	48	-0.9	1.2	4.05	53.7	64	Unsuitable
15	3/34	910	1400	38	-1.4	0.5	1.76	30.7	44	suitable
16	4/5	975	1500	39	-1.8	0.9	3.15	45.6	59	Suitable
17	4/7	1111	1710	47	-0.9	1.0	3.33	47.6	61	Suitable
18	4/13	975	1500	38	-4.3	0.8	3.27	42.1	52	Suitable
19	4/23	1053	1620	51	-1.2	0.6	2.21	36.3	49	Unsuitable
20	4/28	1261	1940	46	-2.9	0.8	2.55	43.3	62	Suitable
21	4/36	1287	1980	58	-1.5	1.0	3.22	48.7	64	Unsuitable
22	4/39	988	1520	54	-2.6	1.2	3.93	53.3	69	Unsuitable

Assessment of Groundwater quality for Older Alluvial Aquifer

Sr, No	Well No	EC	TDS	MAR	RSBC	KR	SAR	SSP	PI	Remark
1	1/5	1210	786	28	-3.08	0.7	2.87	42.98	54	Suitable
2	1/9	1200	780	29	-1.97	1.1	3.62	52.70	64	Unsuitable
3	1/10	1100	715	33	-0.92	1.6	4.49	62.53	75	Unsuitable
4	1/11	1190	773.5	39	-1.43	1.1	3.58	52.82	64	Unsuitable
5	1/14	1210	786.5	42	-0.92	1.3	4.22	56.89	68	Unsuitable
6	1/17	1200	780	39	-2.55	0.9	3.48	48.25	58	Suitable
7	1/28	1220	793	37	-0.25	1.6	4.26	62.30	77	Unsuitable

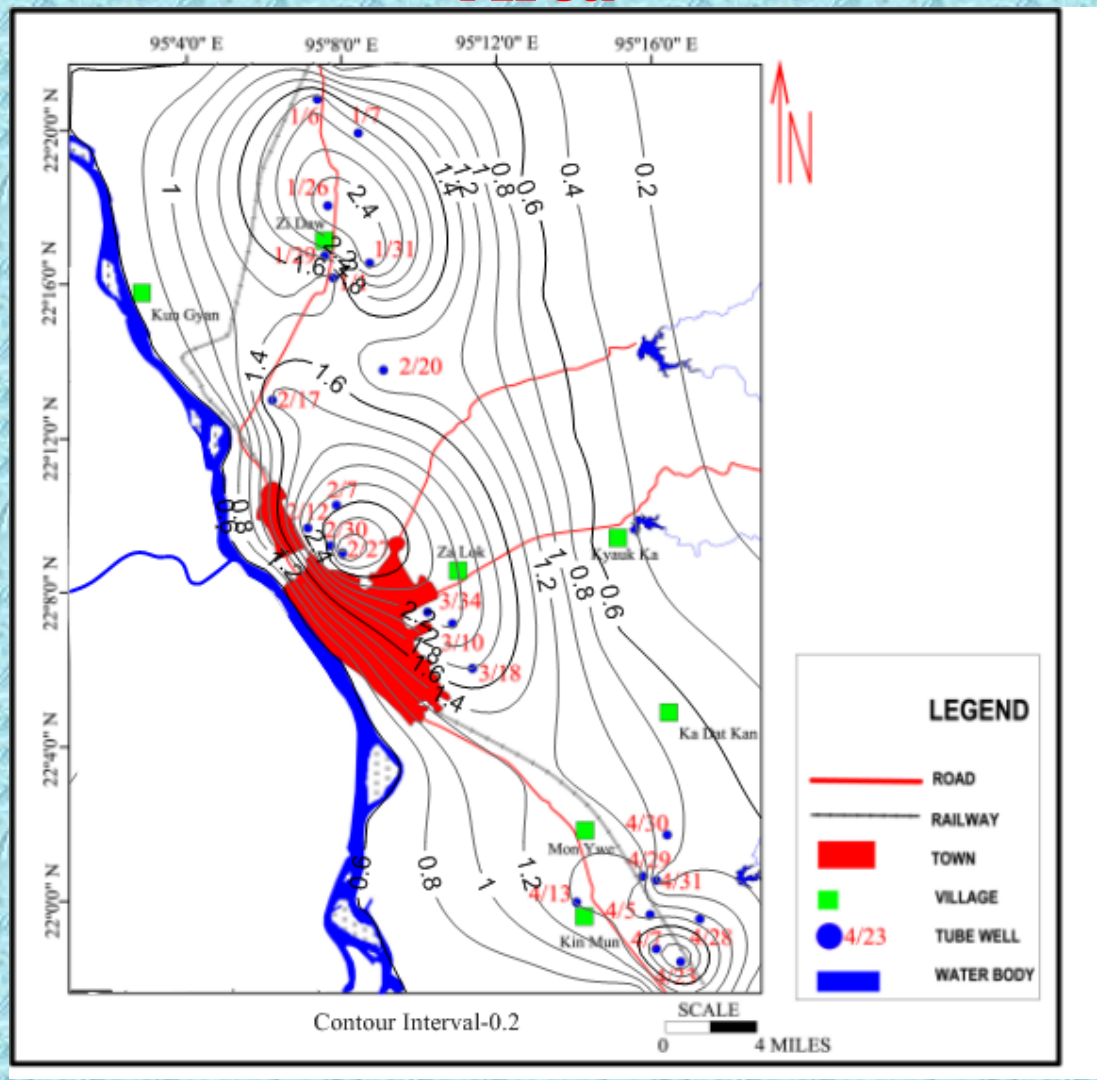
Assessment of Groundwater quality for Irrawaddian Aquifer

Sr, No	Well No	EC	TDS	SAR	SSP	MAR	RSBC	KR	PI	Remark
1	1/18	690	449	2.24	41	41	-1.84	0.7	53	Suitable
2	1/23	825	536	2.26	44	46	-0.81	0.8	59	Suitable
3	2/31	950	618	2.79	46	45	-1.51	0.8	57	Suitable
4	2/32	950	618	2.68	43	48	-1.49	0.8	55	Suitable
5	2/33	1000	650	3.21	50	47	-0.64	1.0	63	Suitable
6	2/11	780	507	3.74	56	33	-0.95	1.3	70	Unsuitable
7	2/13	950	618	2.75	47	26	-2.04	0.9	60	Suitable
8	2/18	1000	650	2.46	42	40	-1.66	0.7	55	Suitable
9	2/22	1000	650	2.89	50	44	-0.8	1.0	64	Suitable
10	2/24	1000	650	1.97	38	61	-0.4	0.6	52	Unsuitable
11	2/25	1000	650	3.04	49	51	-0.63	1.0	63	Unsuitable
12	2/26	1000	650	2.73	48	68	0.29	1.0	66	Unsuitable
13	3/3	1000	650	2.61	43	39	-0.62	0.7	58	Suitable
14	3/4	1000	650	3.62	47	35	-2.51	0.9	57	Suitable
15	3/5	955	621	3.53	53	41	-1.31	1.1	65	Unsuitable
16	3/11	865	562	2.74	48	22	-2.19	0.9	61	Suitable
17	3/12	920	598	3.53	54	24	-1.95	1.2	68	Unsuitable
18	3/19	1000	650	2.39	38	62	-1.12	0.6	48	Unsuitable
19	3/21	945	614	2.09	36	64	-1.23	0.5	46	Unsuitable
20	3/23	1000	650	2.5	45	30	-1.97	0.8	58	Suitable
21	3/25	600	390	0.87	23	36	-1.6	0.3	41	Suitable
22	3/26	700	455	1.94	40	45	-1.18	0.6	54	Suitable
23	3/27	600	390	1.82	40	38	-1.35	0.6	55	Suitable
24	3/29	750	488	2.67	54	46	0.08	1.2	74	Unsuitable
25	3/30	1000	650	1.84	35	30	-3.05	0.5	46	Suitable
26	3/31	800	520	1.75	37	26	-1.8	0.6	54	Suitable
27	4/35	885	575	2.5	49	48	-0.07	0.9	66	Suitable
28	4/15	880	572	2.34	44	41	-1.45	0.8	57	Suitable
29	4/18	920	598	2.9	48	34	-2.97	0.7	52	Suitable
30	4/20	925	601	1.9	40	32	-3.31	0.4	42	Suitable

Hydrochemical Ratio (Coefficients) Environment and Types

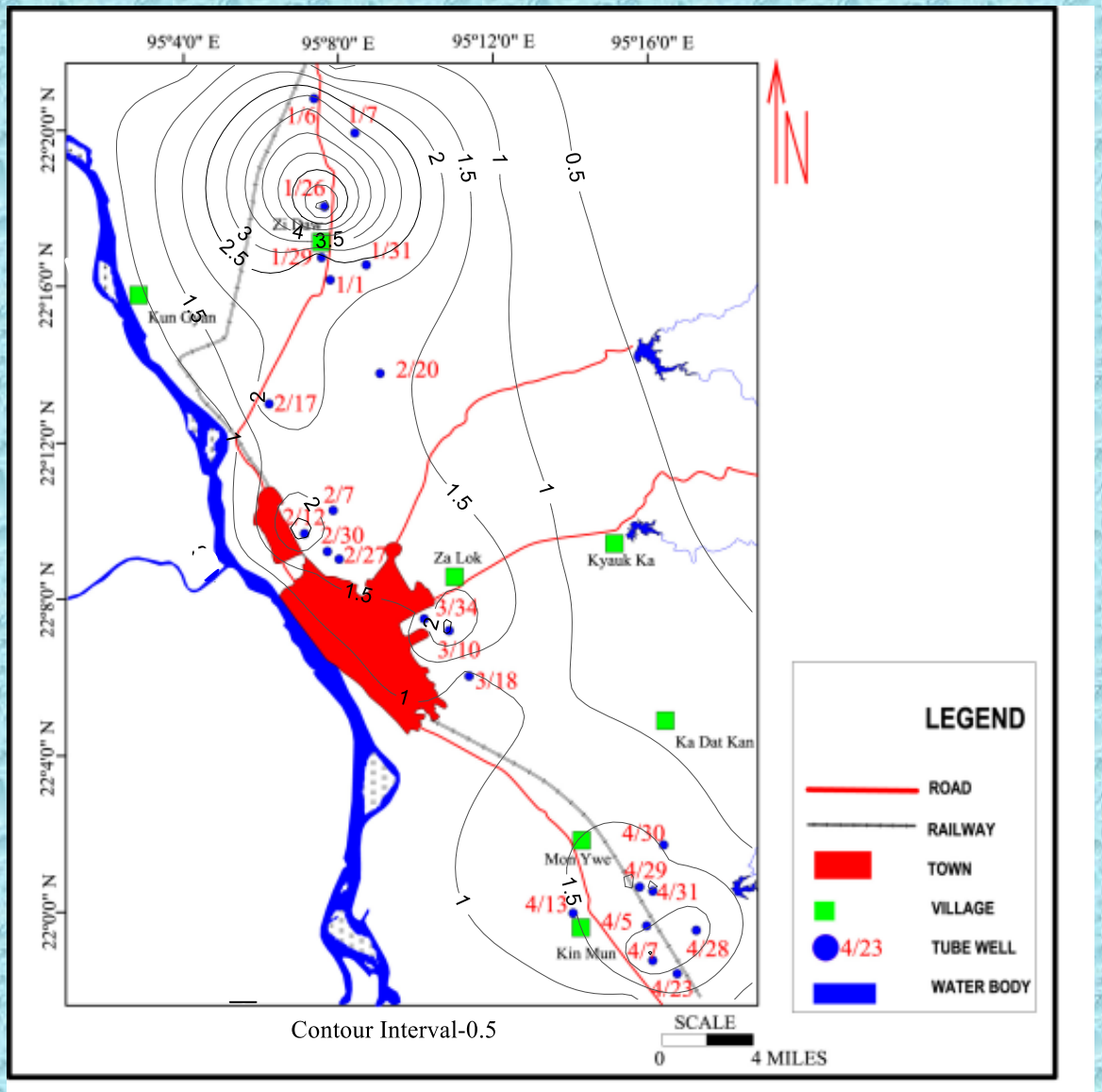
- Ionic ratio were studied to check local replenishment of fresh water, lowering potentiometric surface and origin of groundwater
- Here by three ratios, i.e. Cl^-/ HCO_3, $Cl^-/SO^{=}_4$ and Mg^{++}/Ca^{++}

Distribution of Cl^-/ HCO^-_3 ratio in groundwater at Monywa Area



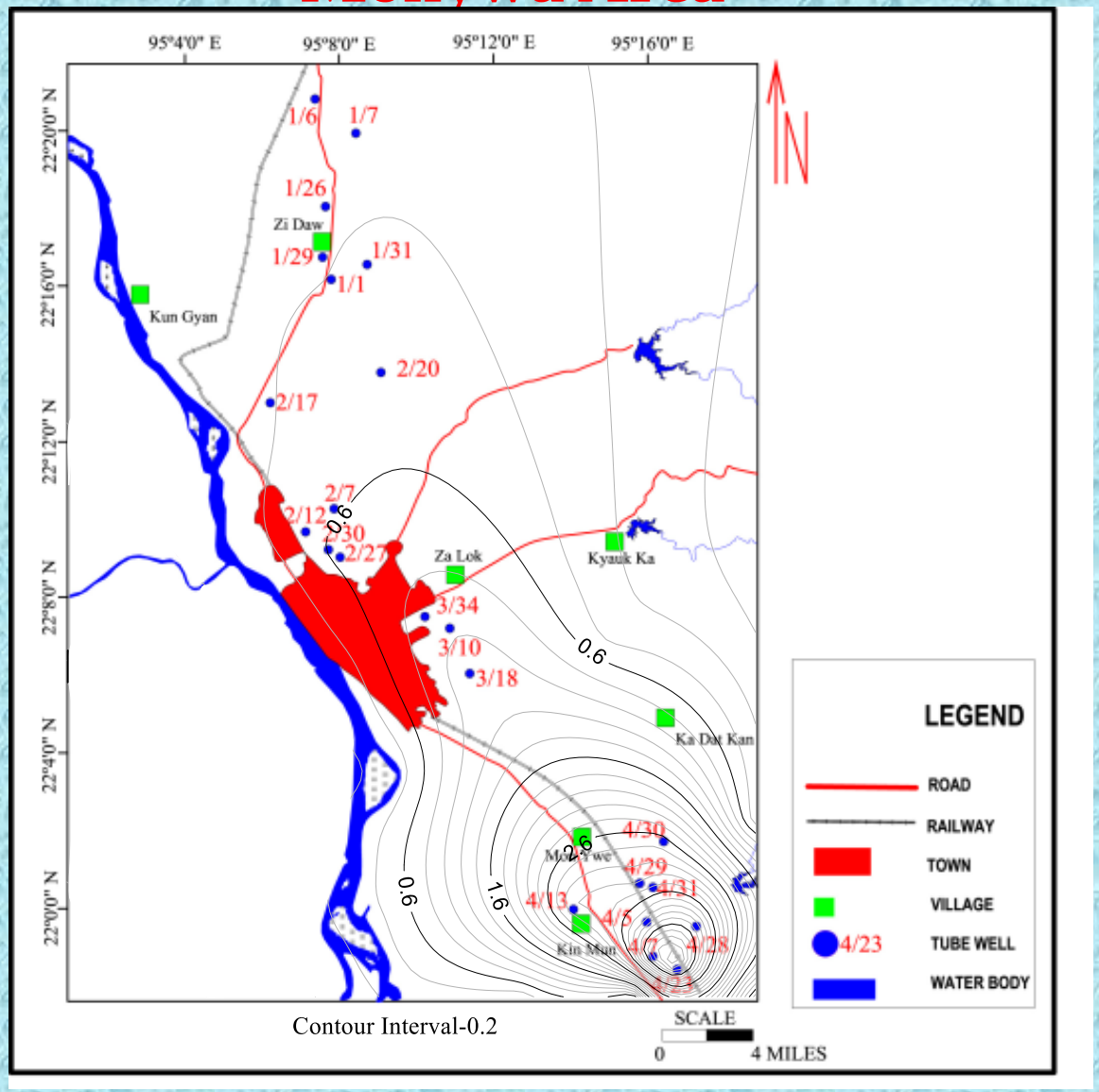
The small value of the ratio found along the Chindwin River and eastern part of the study area and that clearly define the nature of local replenishment by fresh water surface

Distribution of $Cl^-/SO^{=}_4$ ratio in groundwater at Monywa Area



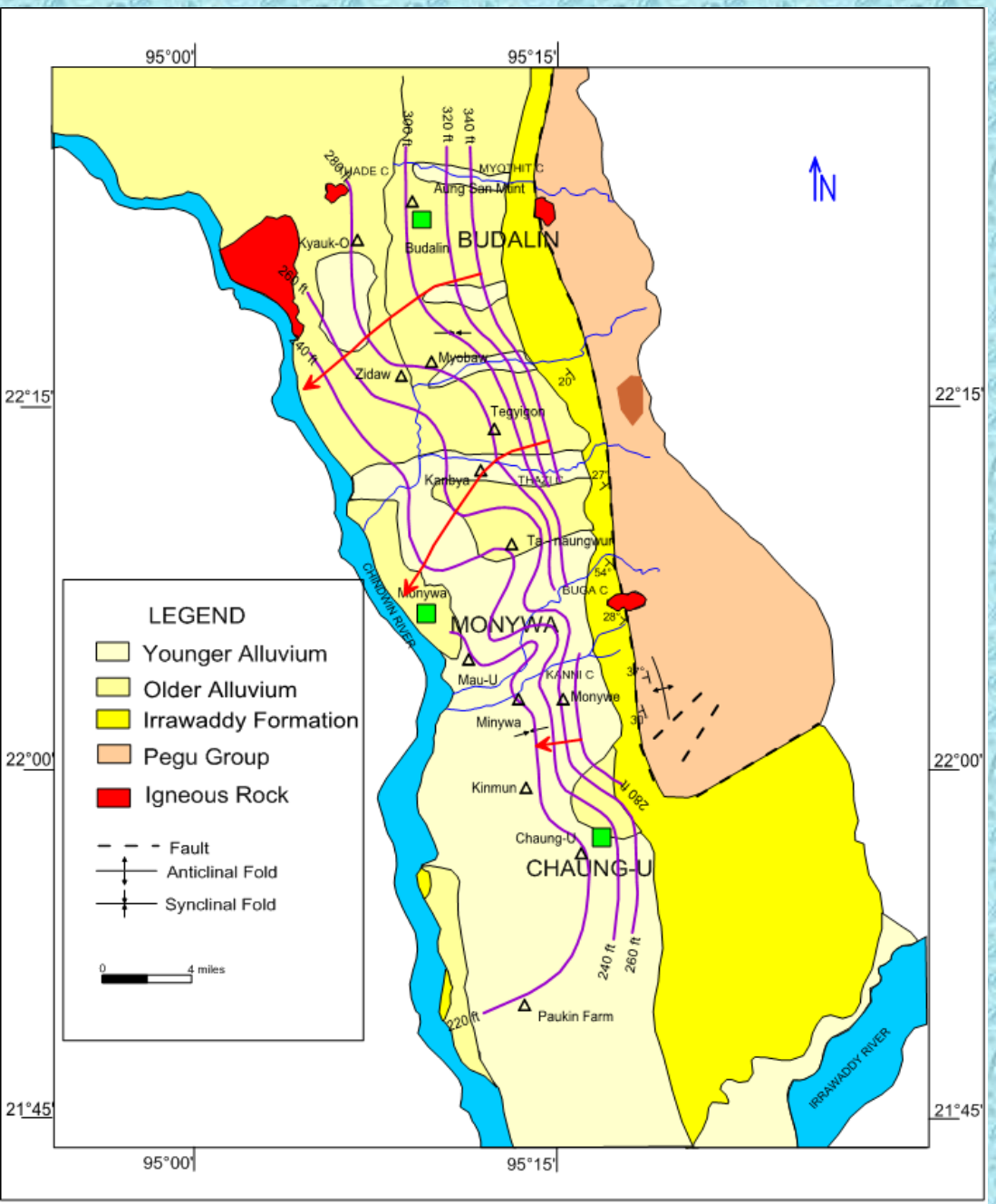
Higher Cl^-/SO^{2-}_4 ratio at the area is reflected by the lowering of potentiometric surface of groundwater

Distribution of Mg^{++} / Ca^{++} ratio in groundwater at Monywa Area



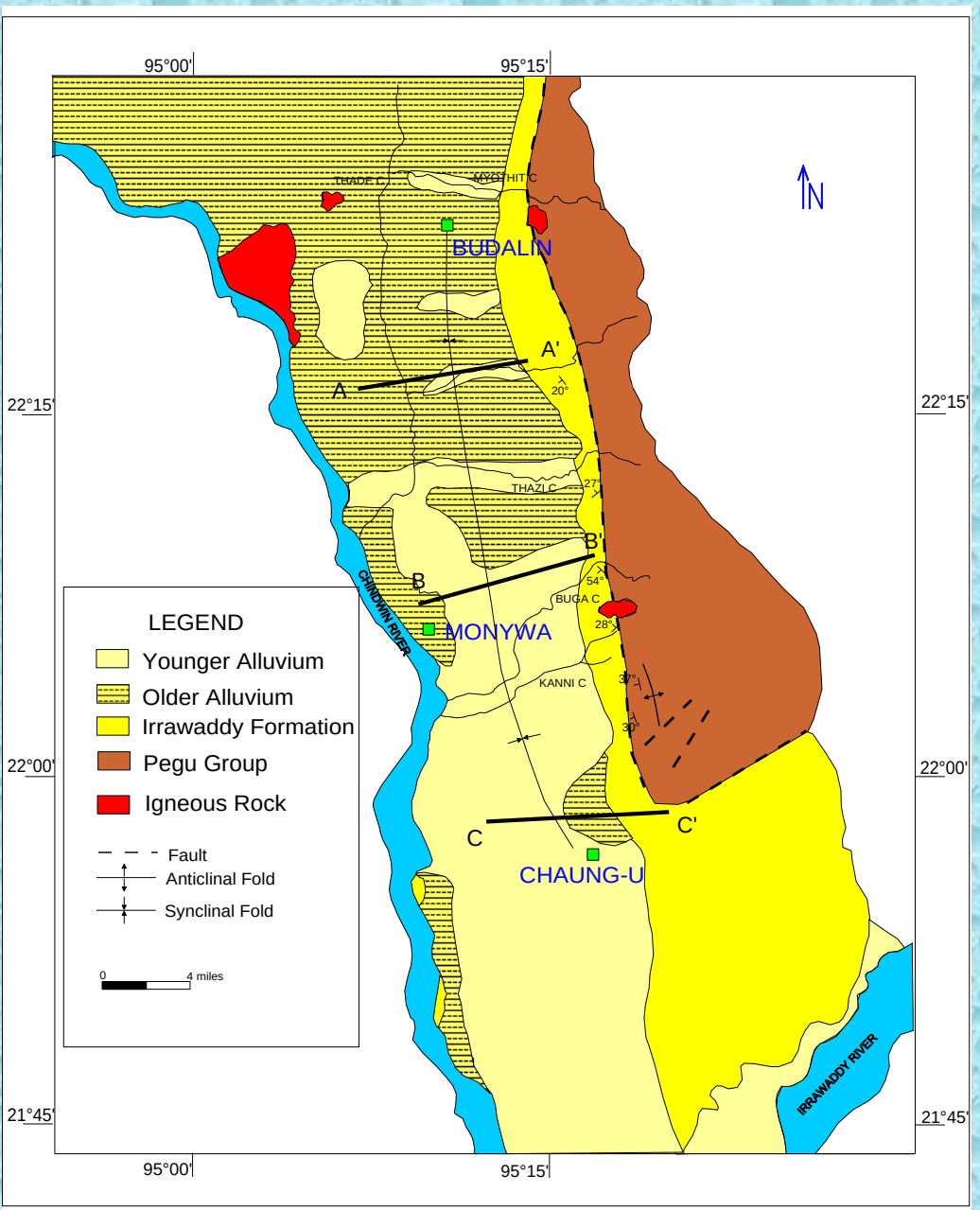
- Mg^{++} / Ca^{++} ratio were all less than 2 ranging from 0.32 to 1.04.
- The groundwater in the study area is inland origin .
- Water under marine influence would have value of about 5.

Hydraulic Characteristics of the Monywa Area



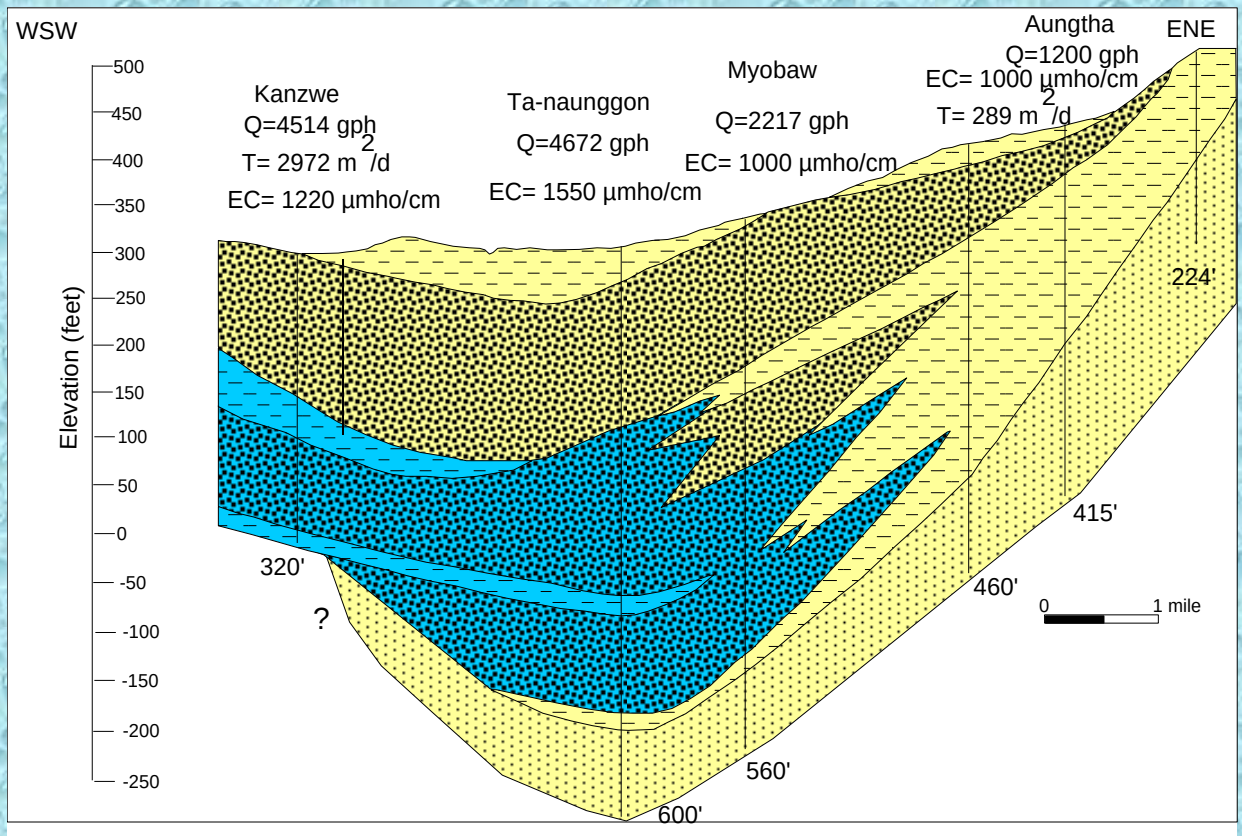
Hydrogeological Map of Monywa Area

Groundwater flow direction is generally East to West



Source from MGS (2014) and U Tun Lwin (1981)

Hydrogeological Cross Section lines of the Study Area

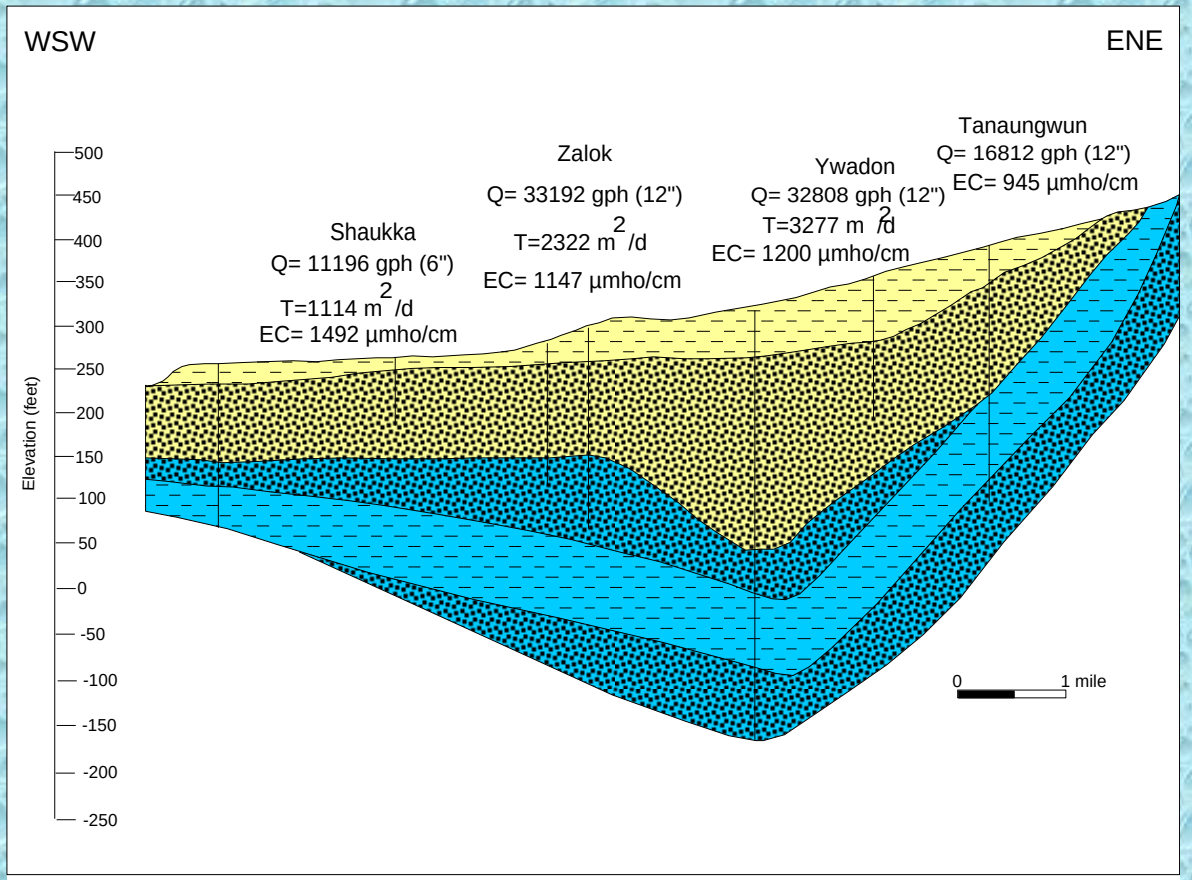


Soucce from Burna Umbrella Project(1984)

LEGEND

- Yellow clay
- Blue clay
- Yellow coarse sand
- Yellow coarse sand and gravel
- Blue coarse sand and gravel

Hydrogeological Cross Section of the Budalin Area(A-A')

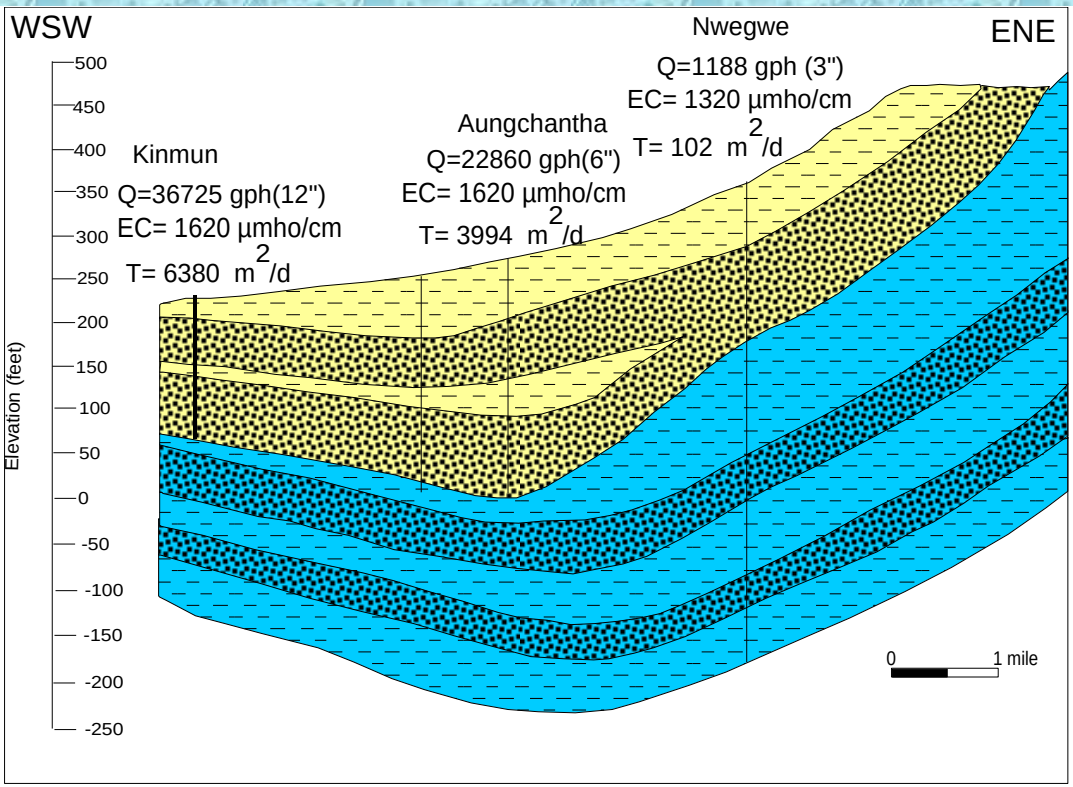


Soucce from Burna Umbrella Project(1984)

LEGEND

- Yellow clay
- Blue clay
- Yellow coarse sand and gravel
- Blue coarse sand and gravel

Hydrogeological Cross Section of the Monywa Area(B-B')



Soucce from Burna Umbrella Project(1984)

LEGEND

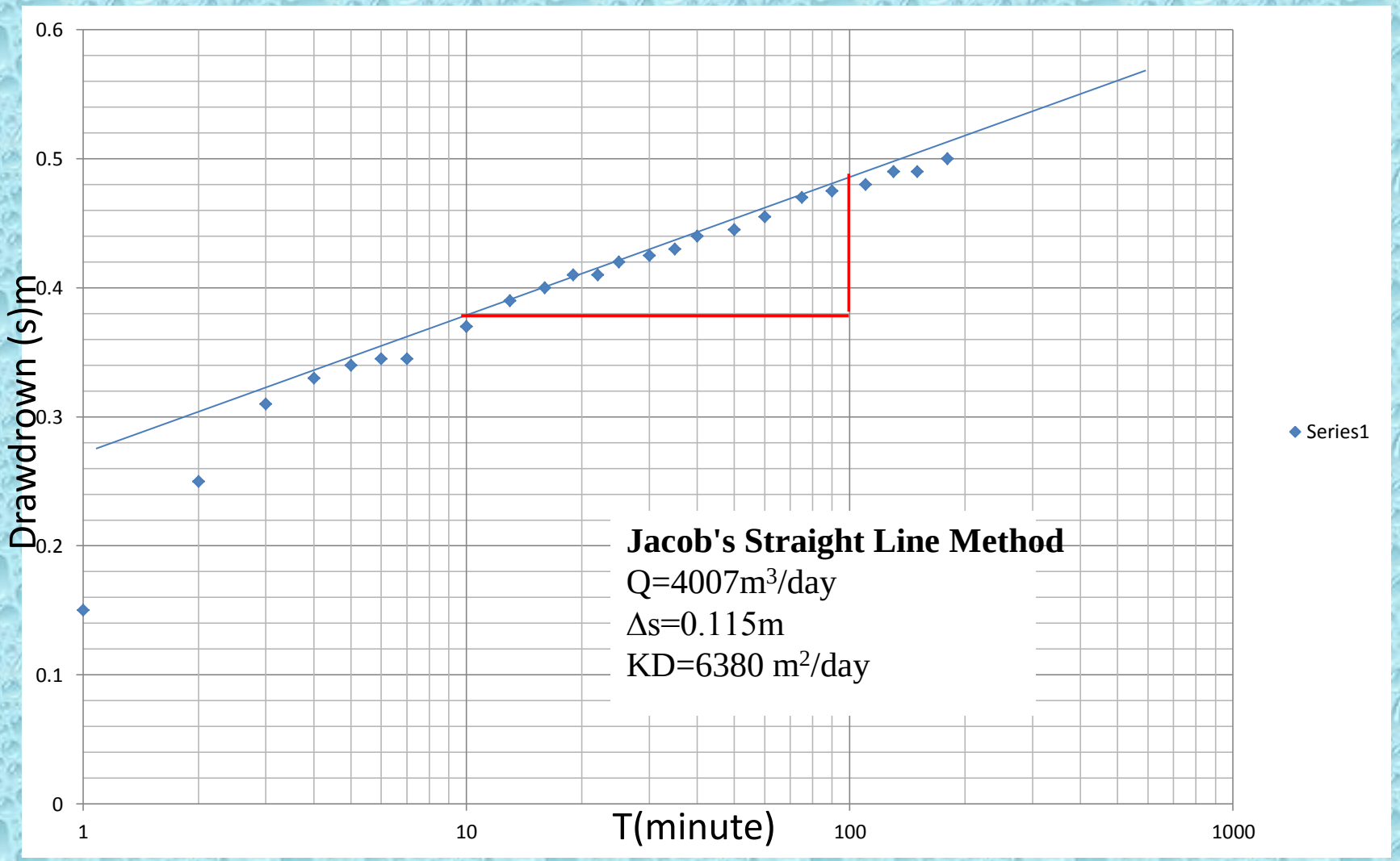
- Yellow clay
- Blue clay
- Yellow coarse sand and gravel
- Blue coarse sand and gravel

Hydrogeological Cross Section of the Chaung-U Area(C-C')

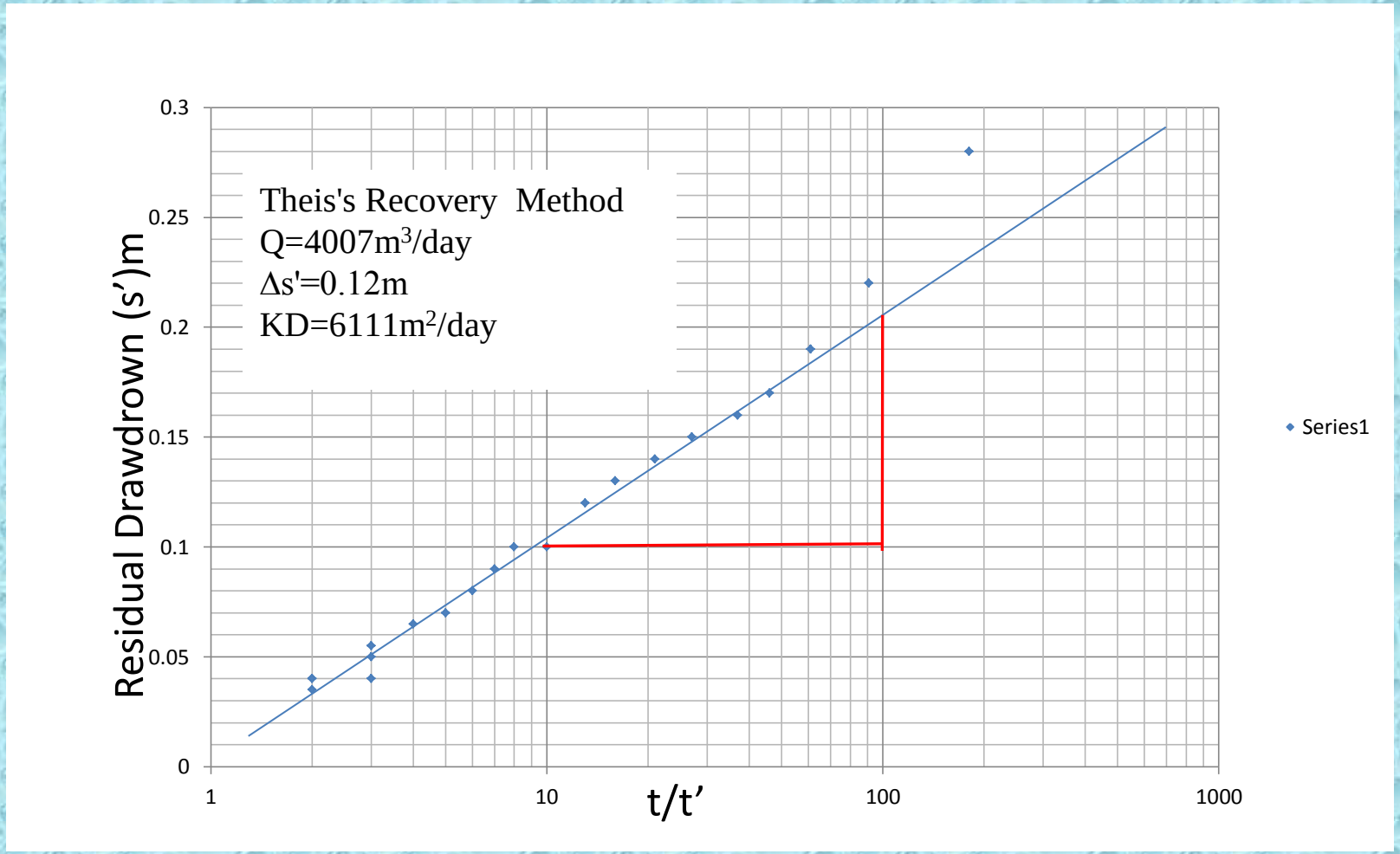
Photograph shows measuring discharge rate

Photograph shows pumping out test at Monywa Township

Pumping Test for Monywa Area



Recovery Test for Monywa Area



- Transmissivity of Alluvial aquifer -1114m^2/d - 6380m^2/d
- Transmissivity of Irrawaddian aquifer -102m^2/d - 289m^2/d
- Storativity of Allivial aquifer - $8x10^{-4}$
- Storativity of Irrawaddian aquifer - $1.8x10^{-5}$

SUMMARY AND CONCLUSION

- The investigated area is located on the north western part of Dry Zone of Central Burma.
- The total coverage area is about 2253 square kilometer
- The Chindwin river on the west of the study area is the main drainage and flows roughly to the S.S.E direction.
- The average annual rainfall is about 635 mm (25 inches).
- Alluvium, Irrawaddian formation, Pegu group and Igneous rock are mainly found in the study area.
- Water in the Alluvial aquifer may cause salinity problems both in irrigation and drinking uses.
- Water in the Irrawaddian aquifer has permanent hardness and does not deposit residual sodium carbonate in irrigation use.

- Transmissivity varies from (1114) to (6380) m^2 / d in Alluvial aquifer.
- Discharge rate of 12 inches diameter well in alluvial aquifer is ranging from 32807 to 36730 gph.
- Transmissivity varies from (102) to (289) m^2 / d in Irrawaddian aquifer.
- The discharge rate of Irrawaddian aquifer is ranging from 4514 gph to 4672 gph for 6 inches diameter tube wells.
- Groundwater flow direction is generally East to West

Thanks for your attention

Conclusion

- Three significant aquifers have been identifying as alluvial aquifer, Irrawaddian aquifer and Peguan aquifer.
- The alluvial aquifer can be sub-divided into compound alluvial fan (bajada), alluvial unit I and II.
- Groundwater of compound alluvial fan aquifer are bicarbonate-chloride calcium-magnesium water and Sulphate sodium water type and most of the water are suitable for irrigation and most of the water are not suitable for drinking water
- Groundwater of alluvial unit I and II are mostly slightly saline to salty water and not suitable in sustainability for irrigation

Conclusion

- Aquifer of the Irrawaddian rocks possess fresh water of bicarbonate and saline and salty water of Chloride sodium water are found
- Pequan aquifer contain saline water of chloride sodium water type
- Distribution patterns of TDS and EC are in total agreement with the nature of groundwater flow from east to west and northwest
- Hydrochemical ratio are determine the area of recharge and potentiometric surface of groundwater
- Suitability of groundwater for irrigation has been evaluated and except the water of compound alluvial fan, most of the groundwater are not suitable for irrigation
- Most of the groundwater of the Pyawbwe-Nyaungyan-Payangazu area is unfit for domestic purposes

- Transmissivity of Alluvial aquifer -1114m^2/d-6380m^2/d
- Transmissivity of Irrawaddian aquifer -102m^2/d-289m^2/d
- Storativity of Allivial aquifer- $8x10^{-4}$
- Storativity of Irrawaddian aquifer- $1.8x10^{-5}$

Thanks You Very Much

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Quality Classification of Water for Irrigation Base on Percent Sodium (Wilcox, 1955)

Water Class	Percent Sodium	Specific Conductance, µS/cm
Excellent	<20	<250
Good	20-40	250-750
Permissible	40-60	750-2000
Doubtful	60-80	2000-3000
Unsuitable	>80	>3000

Classification of irrigation water base on chloride

Chloride levels	Toxicity
<4 meq/l	No problem
4-10 meq/l	1. Increasing problem
>10 meq/l	Severe problem

Results and Assessment of physicochemical qualities of groundwater

pH

pH value is ranging between 6.7 to 9.4, and most of the water are alkaline

Total Dissolved Solid (TDS)

The lowest value of TDS is 260 ppm and the highest value is 1228.5 ppm

Groundwater classification base on TDS

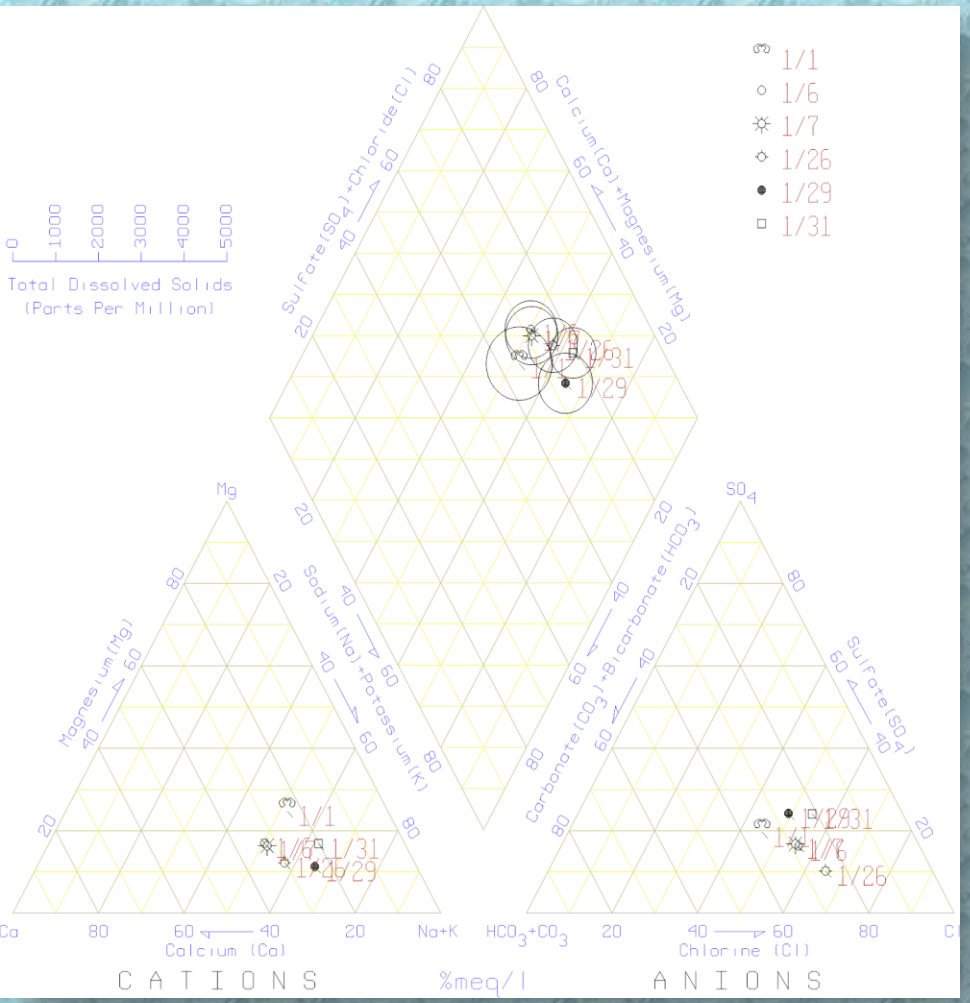
Category	Total Dissolved Solid, mg/l
Fresh	0 – 1,000
Brackish water	1,000 – 10,000
Salty water	10,000 – 100,000
Brine water	More than 100,000

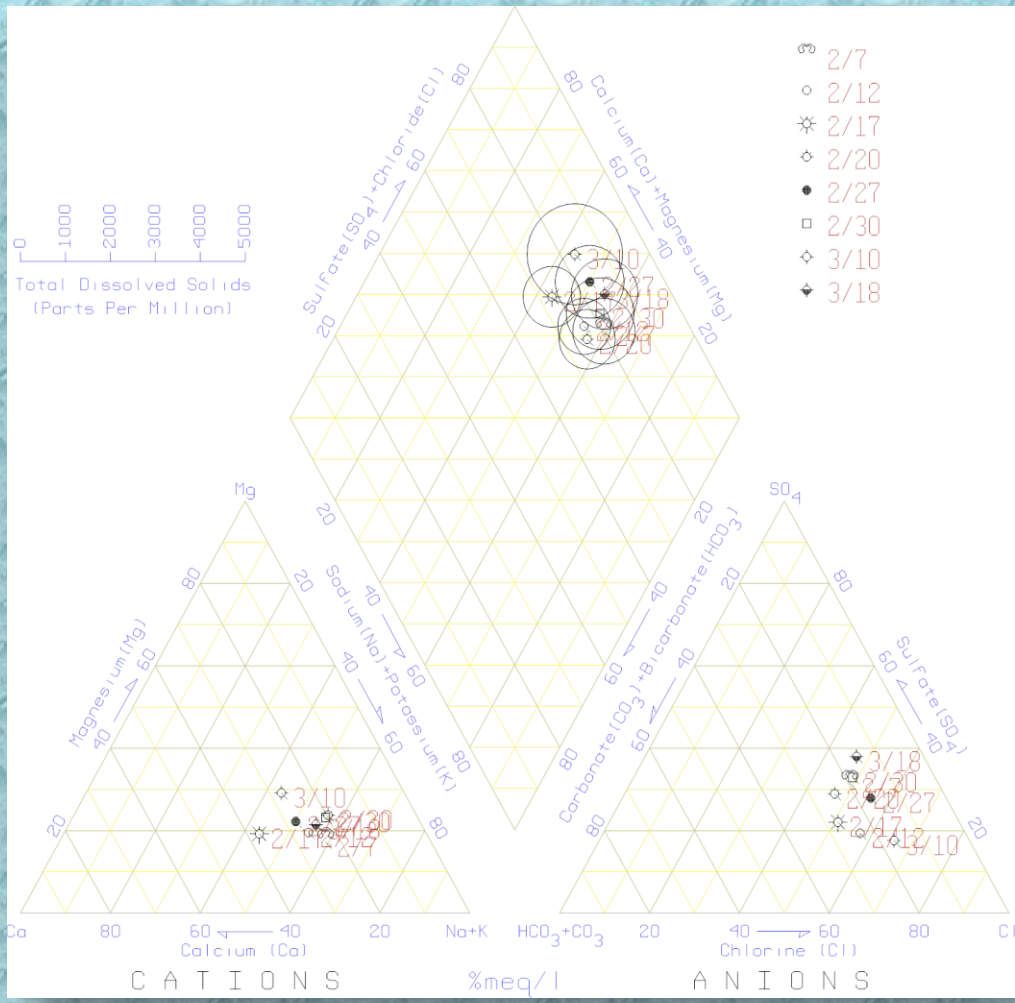
Electrical conductivity (EC)

- The value of E.C. are ranging from 400 µmhos/cm to 1890 µmhos/cm
- EC has been used to evaluate the quality of irrigation water and salinity levels and their classification are:

Salinity zone EC, µmhos/cm	Class
0 – 750	No problem
750 – 2750	Increasing problem
Above 2750	Severe problem

Piper diagram of hydrochemical facies of groundwater component from Younger Alluvial Aquifer





Dominant Water Type Ca^{++}-Mg^{++}- Na^{+} HCO^{-}_{3}-Cl^{-}-$SO_4^{=}$

Minor Water Type Ca^{++}-Mg^{++}- Na^{+} $SO_4^{=}$-Cl^{-}

Classification of the analyzed water sample with respect to adsorption ratio and salinity hazard (After US Salinity lab, 1954)

Classification of water	Electrical conductivity in µmhos/cm at 25ºC	Salt concentration in mg/L (approximately)	Classification of water
C1- Low salinity water	0< EC ≤ 250	200	S1- low sodium water
C2- Medium salinity water	250< EC ≤ 750	200 – 500	S2- Medium sodium water
C3- High salinity water	750< EC ≤ 2250	500 – 1500	S3- High sodium water
C4- Very high salinity water	2250< EC ≤ 5000	1500 - 3000	S4- Very high sodium water

Class	Type
C1S1, C2S1,	Excellent
C1S2, C2 S2,	Good
C1S3, C2S3, C3S1, C4S2, C3S2	Fair
C1S4, C2S4, C3S4, C4S4, C4S3	poor

RSBC (meq/l)	Sustainability for Irrigation
<1.25	Excellent
1.25 – 2.5	Good
> 2.5	Fair

Comparison with allowable drinking water standard WHO (2011)

Parameter	Range		Mean	WHO (2006)
	Minium	Maximum		
pH	6.22	7.77	6.9	6.5 - 8.5
Electrical Conductivity (µmhos/cm)	1350	2100	1592	1500
Sodium (mg/L)	79	167	130	200
Potassium (mg/L)	2.1	17	6.5	-
Calcium (mg/L)	31	114	64	200
Magnesium (mg/L)	14	52	30	150
Iron (mg/L)	2	6	3.7	1
Chloride (mg/L)	134	283	206	250
Sulphate (mg/L)	42	200	118	250
Bicarbonate (mg/L)	100	244	140	-
TDS (mg/L)	877	1365	1034	1000
Total Hardness (mg/L)	154	464	287	500
CO_3	0	0	0	-

Potential Salinity (PS) in Younger Alluvial Aquifer , (Doneen, 1964)

❖An important parameter “Potential Salinity” (PS) for assessing the suitability of water quality for irrigation.

❖Excessive salinity occurs when there is an accumulation of salts in top soils.

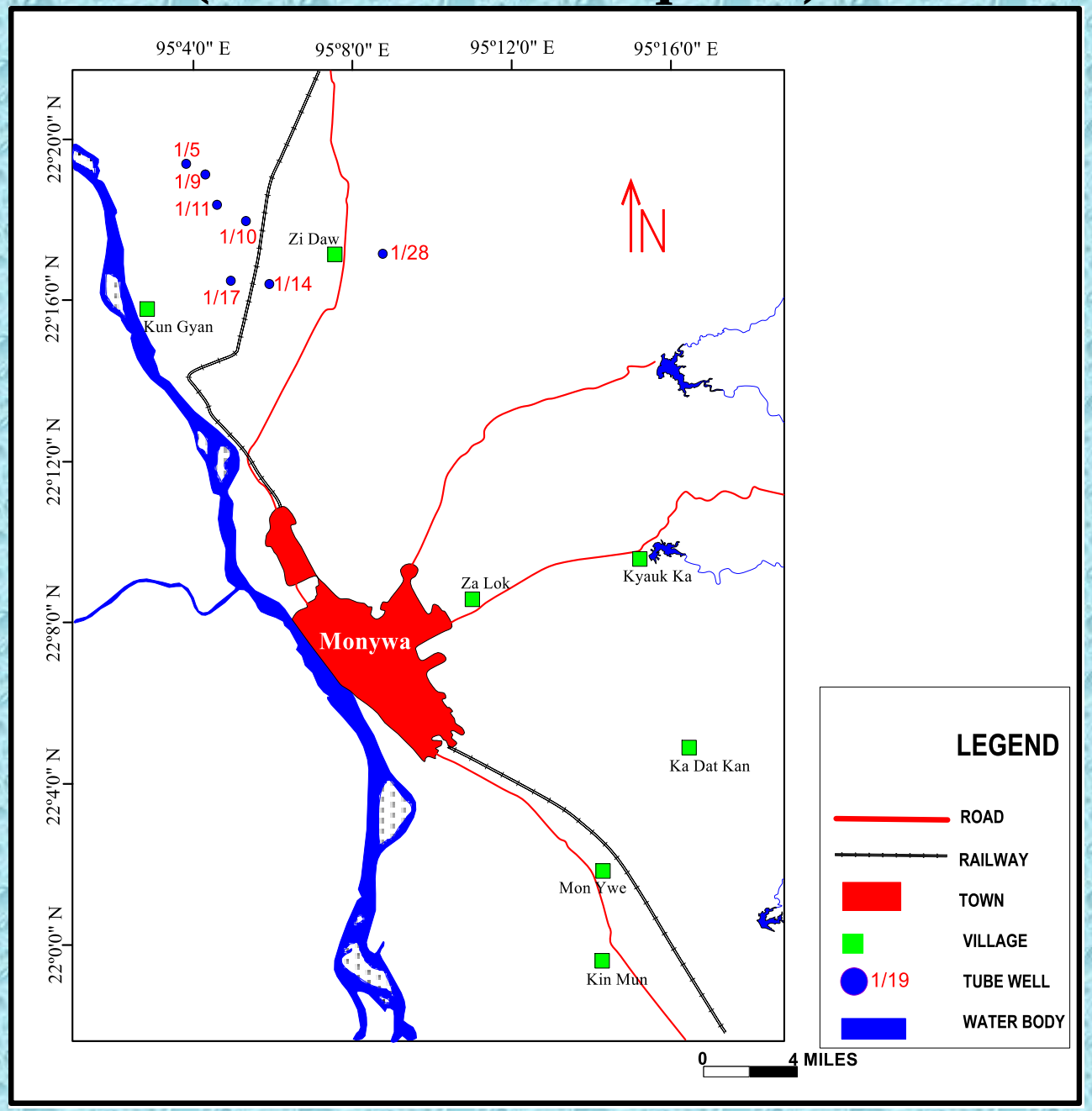
❖Soil permeability can be reduced by the built up of salts.

❖Crop production is reduced.

$$PS = Cl + 1/2\ SO_4 \text{ Unit (meq/l)}$$

The allowable unit of Potential Salinity (PS) is<1.5 to 5. The PS value of the Younger Alluvial Aquifer is ranging from 5-13.8 meq/l. So, it is not suitable for irrigation.

Chemical tube wells location map of the study area (Older alluvial Aquifer)



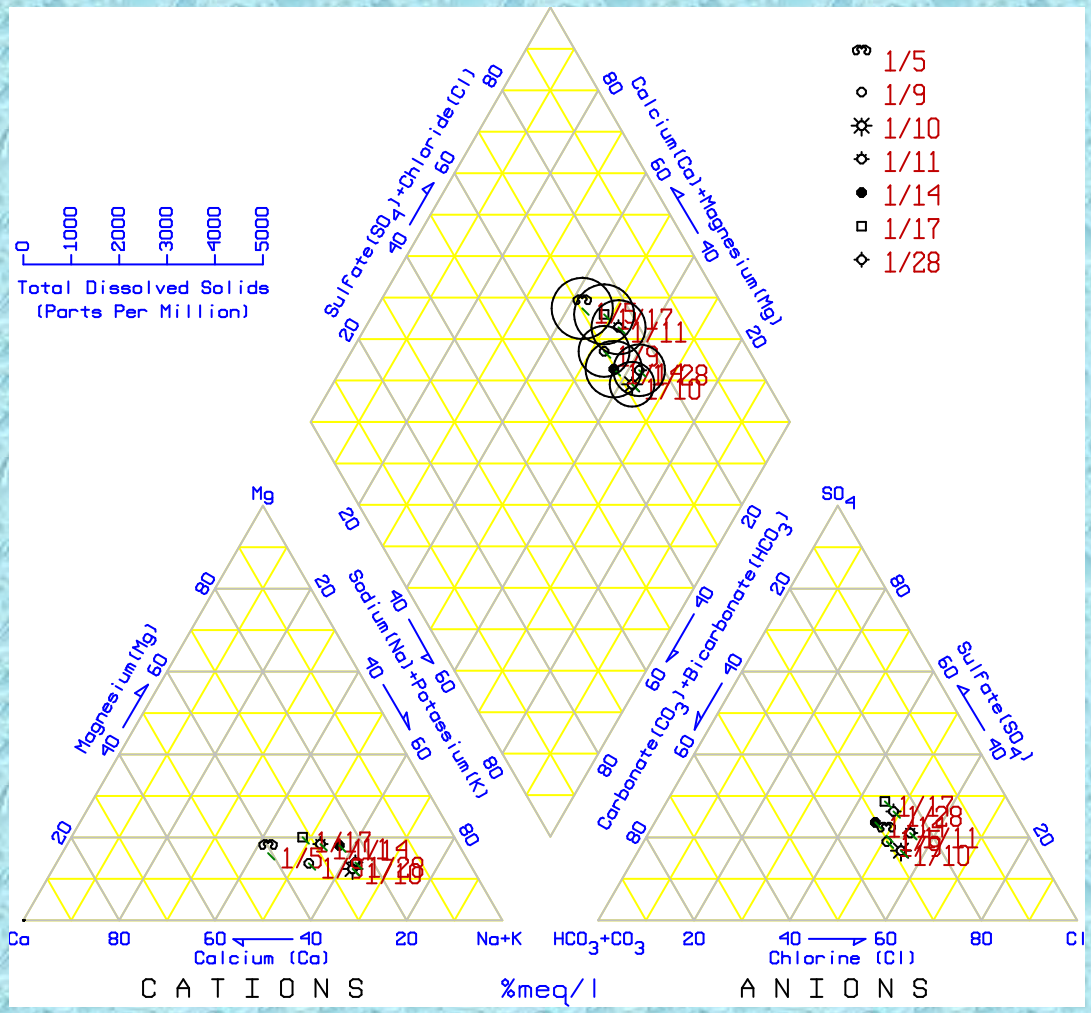
Chemical Analysis Data of Groundwater from Older Alluvial Aquifer

Sr, No	Well No	EC	TDS	pH	Concetration of ions in milligram per litre									Total Hard ness
					Fe (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	CL (mg/l)	
1	1/5	1210	786.5	6.8	2.5	129	6	109.7	26.41	ND	146	79.2	143	384
2	1/9	1200	780	6.67	3.5	138	5	78.16	19.44	ND	118	58.32	115	276
3	1/10	1100	715	6.66	3	142	5.5	50.72	15.24	ND	98	45.72	110	192
4	1/11	1190	773.5	6.56	3	135	5.4	65.62	25.44	ND	112	76.32	146	270
5	1/14	1210	786.5	6.5	2.5	159	6.5	62.43	27.36	ND	134	82.08	118	270
6	1/17	1200	780	6.87	2	153	6.5	89.81	34.44	ND	118	103.32	121	368
7	1/28	1220	793	6.76	2.5	129	4.5	43.69	15.6	ND	118	96.80	132	174

Comparison with allowable drinking water standard WHO (2011) (Older Alluvial Aquifer)

Parameter	Range		Mean	WHO (2006)
	Minium	Maximum		
PH (unit)	6.5	6.87	6.68	6.5 - 8.5
Electrical Conductivity (µmhos/cm)	1100	1220	1190	1500
Sodium (mg/L)	129	159	140	200
Potassium (mg/L)	4.5	6.5	5.6	-
Calcium (mg/L)	43.69	109.7	71	200
Magnesium (mg/L)	15.24	34.44	23	150
Iron (mg/L)	2	3.5	2.7	1
Chloride (mg/L)	110	146	126	250
Sulphate (mg/L)	45.72	103.32	77	250
Bicarbonate (mg/L)	98	146	120	-
TDS (mg/L)	715	793	774	1000
Total Hardness (mg/L)	174	384	276	500
CO_3	0	0	0	-

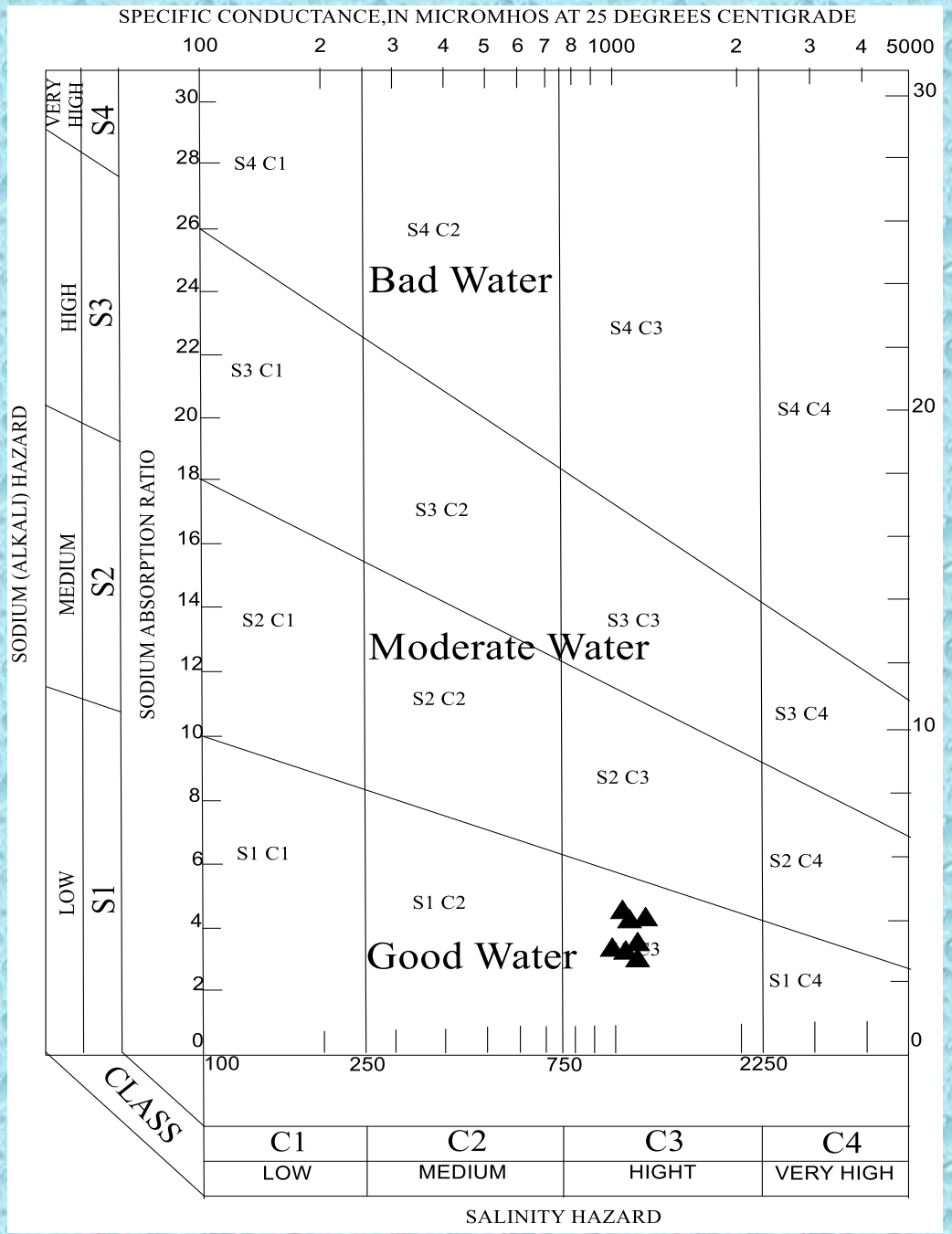
Piper diagram of hydrochemical facies of groundwater component from Older Alluvial Aquifer



Dominant Water Type Ca^{++}- Na^{+} HCO^{-}_{3}-Cl^{-}-$SO_4^{=}$

Minor Water Type Na^{+} HCO^{-}_{3}-Cl^{-}- $SO_4^{=}$

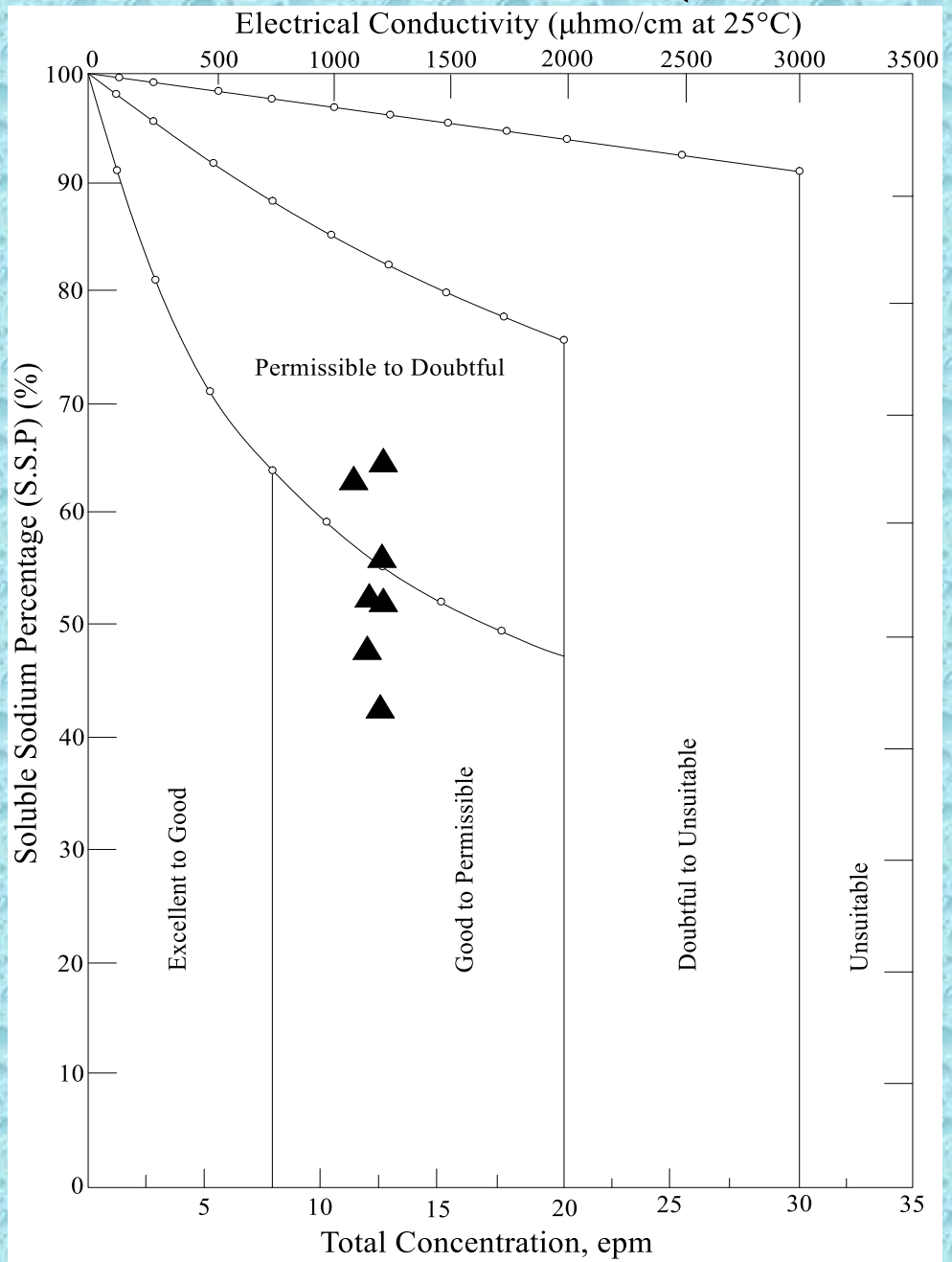
USSL diagram for classification of Irrigation water



Groundwater from Older Alluvial Aquifer are found to occur in classes as:

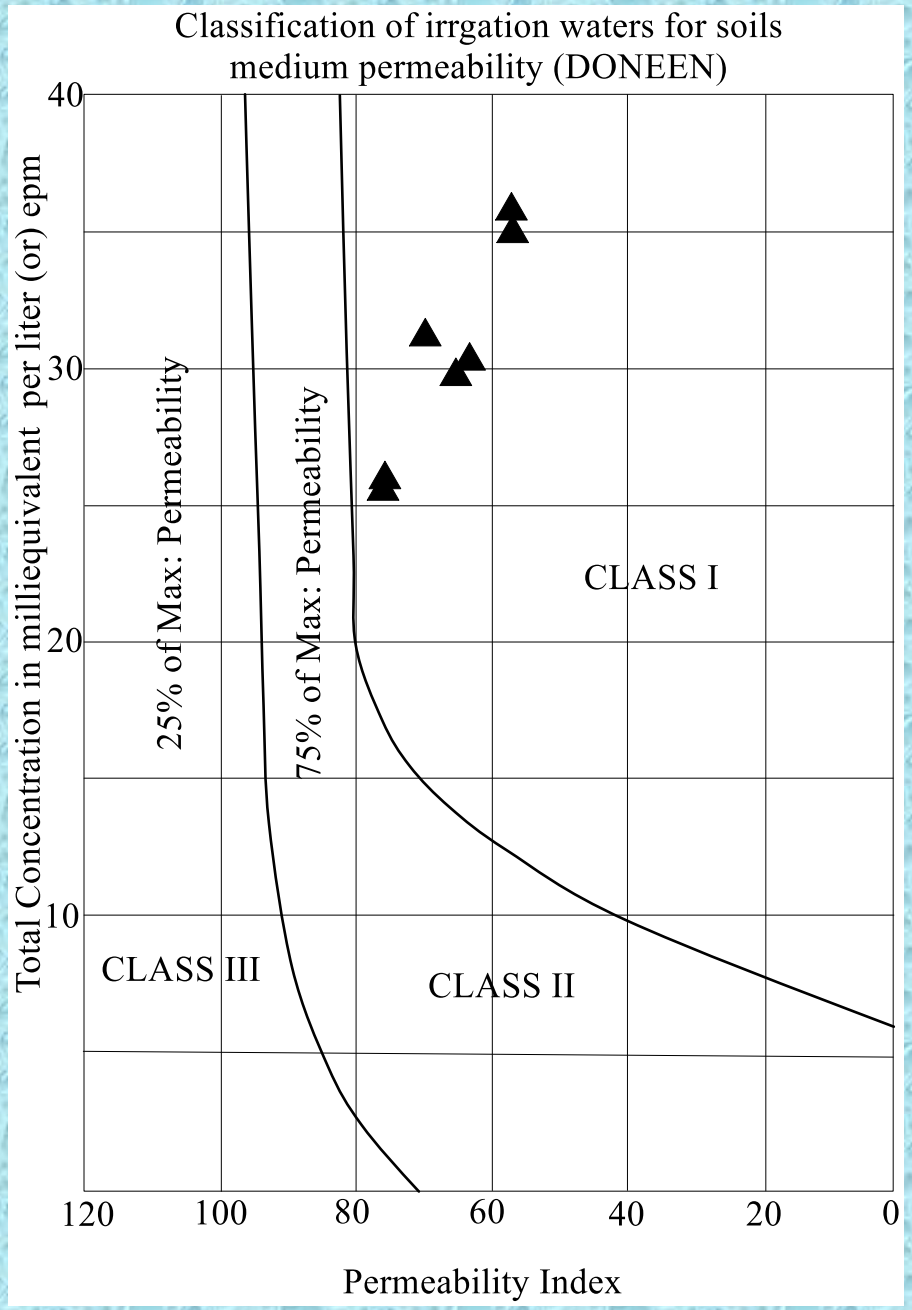
1. $S_1 C_3$ -Low sodium hazard with high salinity hazard

Classification of groundwater for Irrigation Base on Na% (After Wilcox, 1955)



- Most of the groundwater samples are within good to permissible limit and a few samples are permissible to doubtful.

Possible Utilization of Groundwater for Irrigation by Permeability Index



Most of the groundwater samples fall under Class I
Class I is suitable for Irrigation

Summary Statistics of different indices of groundwater for irrigation (Older alluvial aquifer)

Parameter	Minimum	Maximum	Mean
SAR	2.87	4.49	3.8
SSP (%)	42.98	62.53	54
RSBC (meq/L)	-3.08	-0.25	-1.6
PI (%)	54	77	66
MAR (%)	28	42	35
KR	0.7	1.6	1.2
EC µmhos/cm	1100	1220	1190
TDS (mg/L)	715	793	774

Limits of some parameter indices for rating groundwater quality and its sustainability in irrigation (Ayers and Westcot, 1985;Eaton, 1950; Wilcox, 1950)

Category	EC µmhos/cm	TDS (mg/L)	RSBC (meq/L)	SSP (%)	SAR	Sustainability for Irrigation
I	< 250	0 – 1,000	<1.25	<20	<10	Excellent
II	250-750	1,000 – 10,000	1.25-2.5	20-40	10-18	Good
III	750-2250	10,000 – 100,000	>2.5	40-80	18-26	Fair
IV	2250->4000	More than 100,000	-	>80	>26	Poor

Allowable Unit		
Parameter	Minimum	Maximum
SSP (%)	<20	80
RSBC (meq/L)	1.25	2.5
MAR (%)	7.97	50
KR	0	1

Potential Salinity (PS) in Older Alluvial Aquifer , (Doneen, 1964)

❖An important parameter “Potential Salinity” (PS) for assessing the suitability of water quality for irrigation.

❖Excessive salinity occurs when there is an accumulation of salts in top soils.

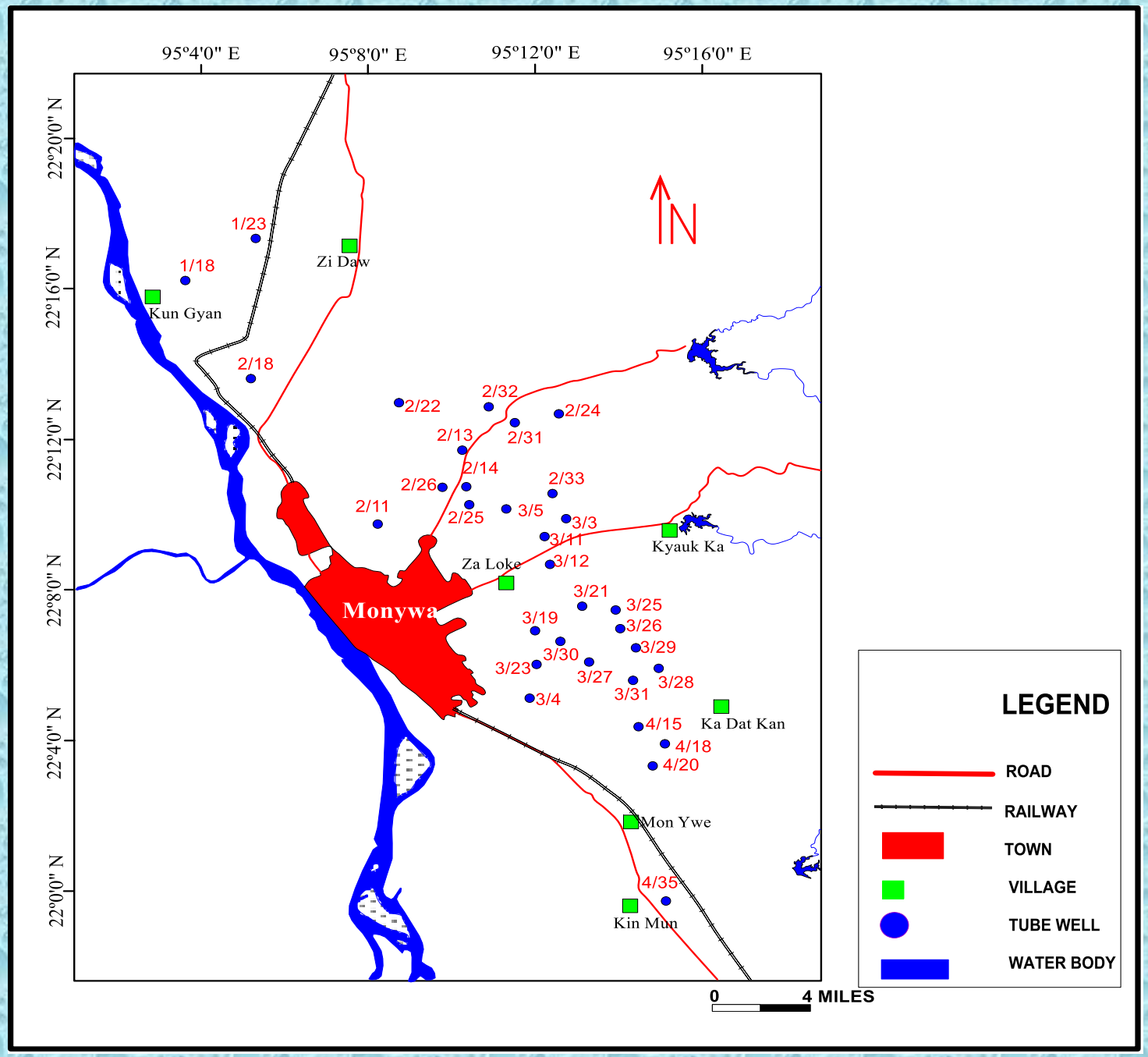
❖Soil permeability can be reduced by the built up of salts.

❖Crop production is reduced.

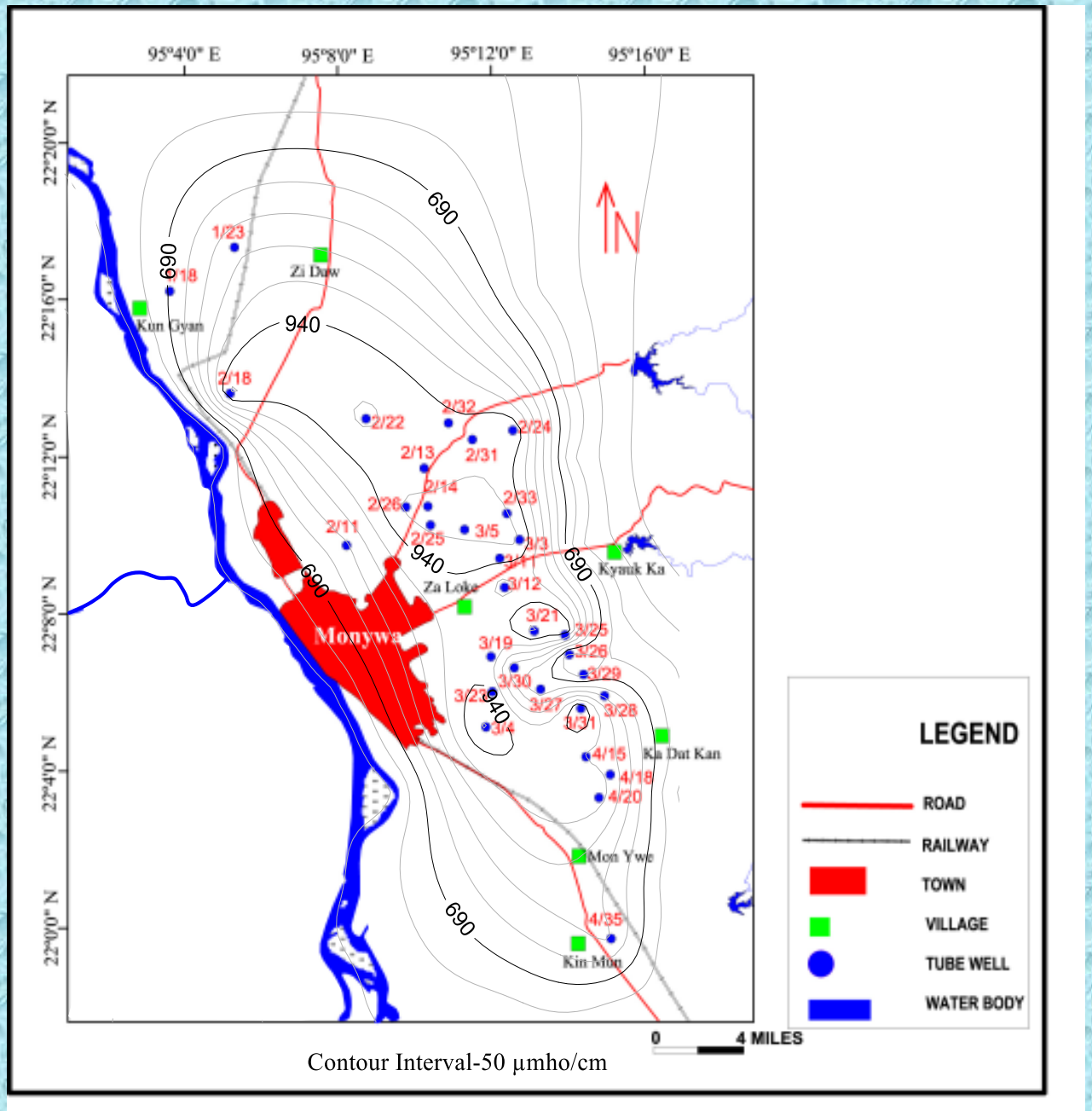
$$PS = Cl + 1/2\ SO_4 \text{ Unit (meq/l)}$$

The allowable unit of Potential Salinity (PS) is<1.5 to 5. The PS value of the Younger Alluvial Aquifer is ranging from 3.6 to 4.9 meq/L.So, it is suitable for irrigation.

Chemical tube wells location map of the study area (Irrawaddian Aquifer)

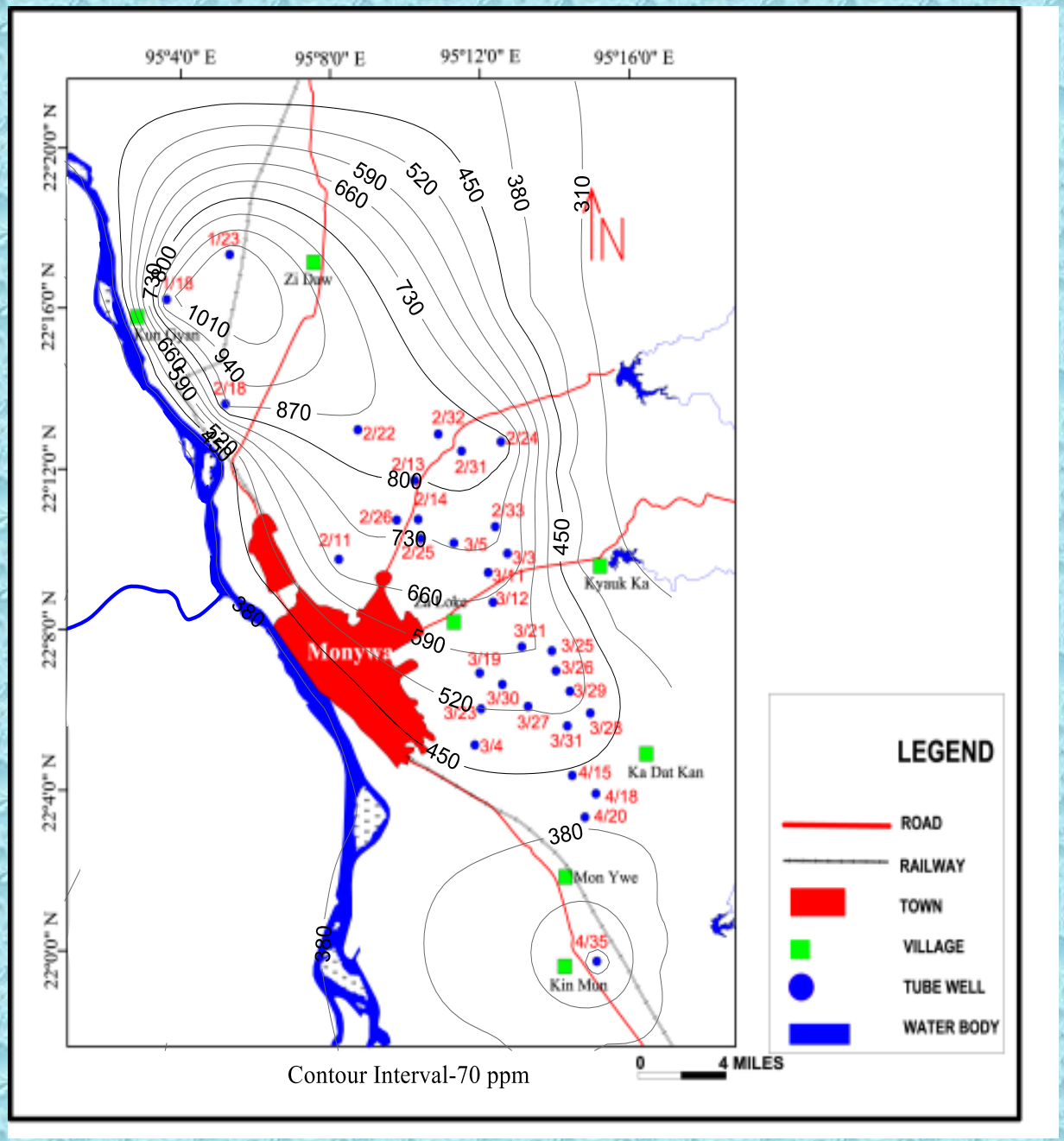


Distribution of Specific Electrical conductance in water Irrawaddian Aquifer in study area



Contour Interval-50 µmho/cm

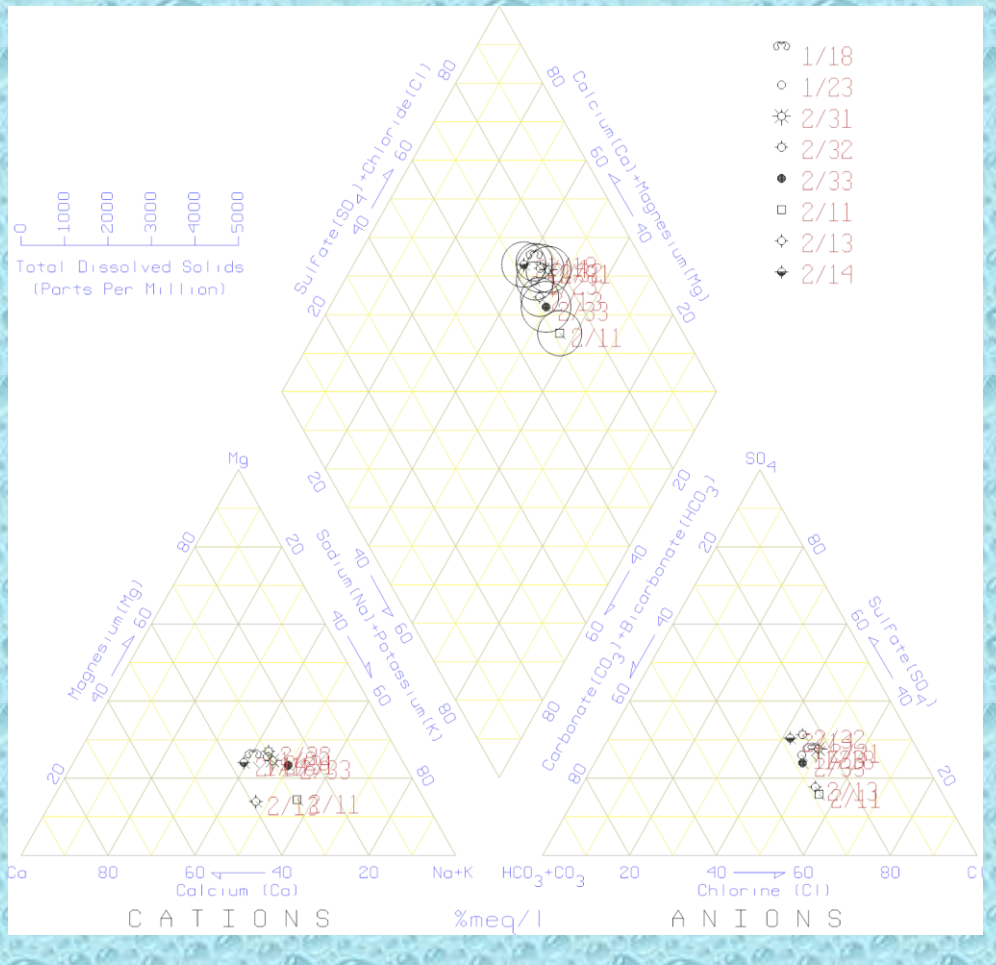
Distribution of Total Dissolved Solid in water of Irrawaddian Aquifer in study area

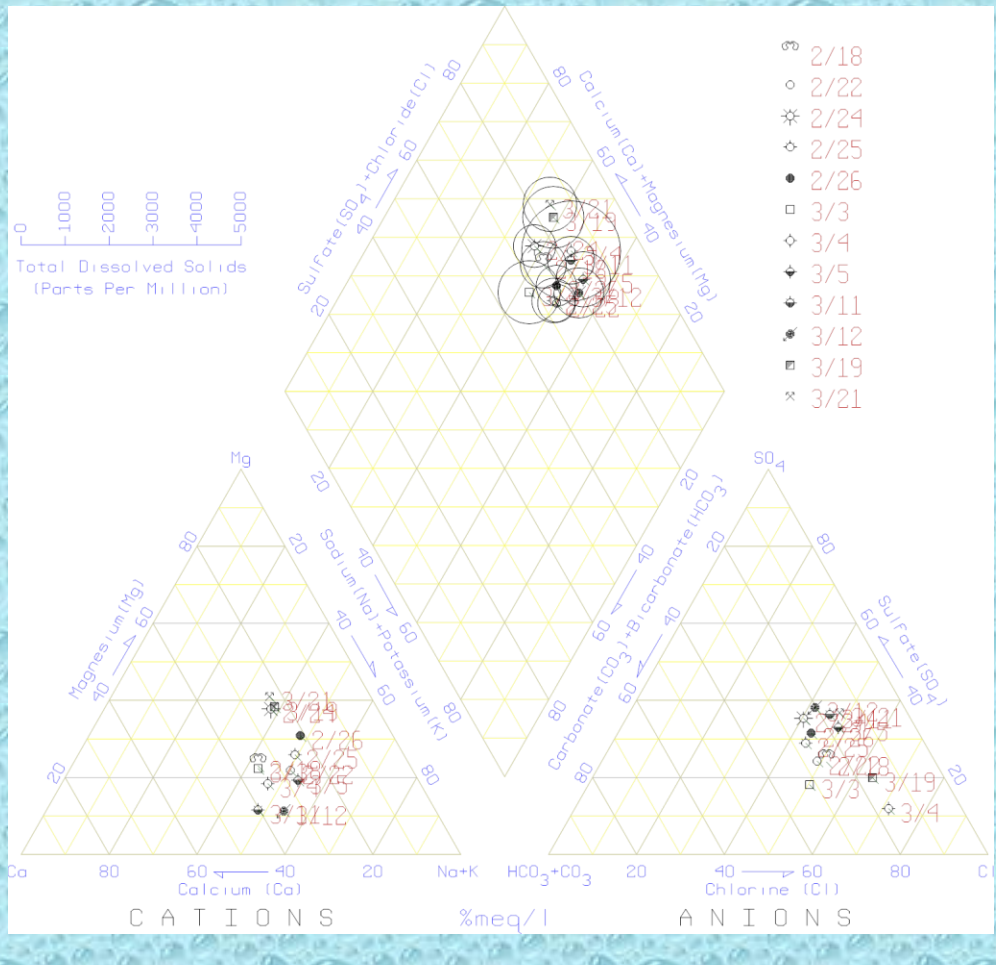


Comparison with allowable drinking water standard W.HO (2011)

Parameter	Range		Mean	WHO (2006)
	Minium	Maximum		
PH (unit)	6.53	7.65	6.54	6.5 - 8.5
Electrical Conductivity (µmhos/cm)	600	1000	896	1500
Sodium (mg/L)	61	174	93	200
Potassium (mg/L)	2	8	3.7	-
Calcium (mg/L)	29.2	88.74	59	200
Magnesium (mg/L)	12.48	58.56	26	150
Iron (mg/L)	1.5	6.5	2.56	1
Chloride (mg/L)	76	488	134	250
Sulphate (mg/L)	47.16	168.04	95	250
Bicarbonate (mg/L)	68	204	103	-
TDS (mg/L)	390	650	582	1000
Total Hardness (mg/L)	194	440	263	500
CO_3	0	0	0	-

Piper diagram of hydrochemical facies of groundwater component from Irrawaddian Aquifer





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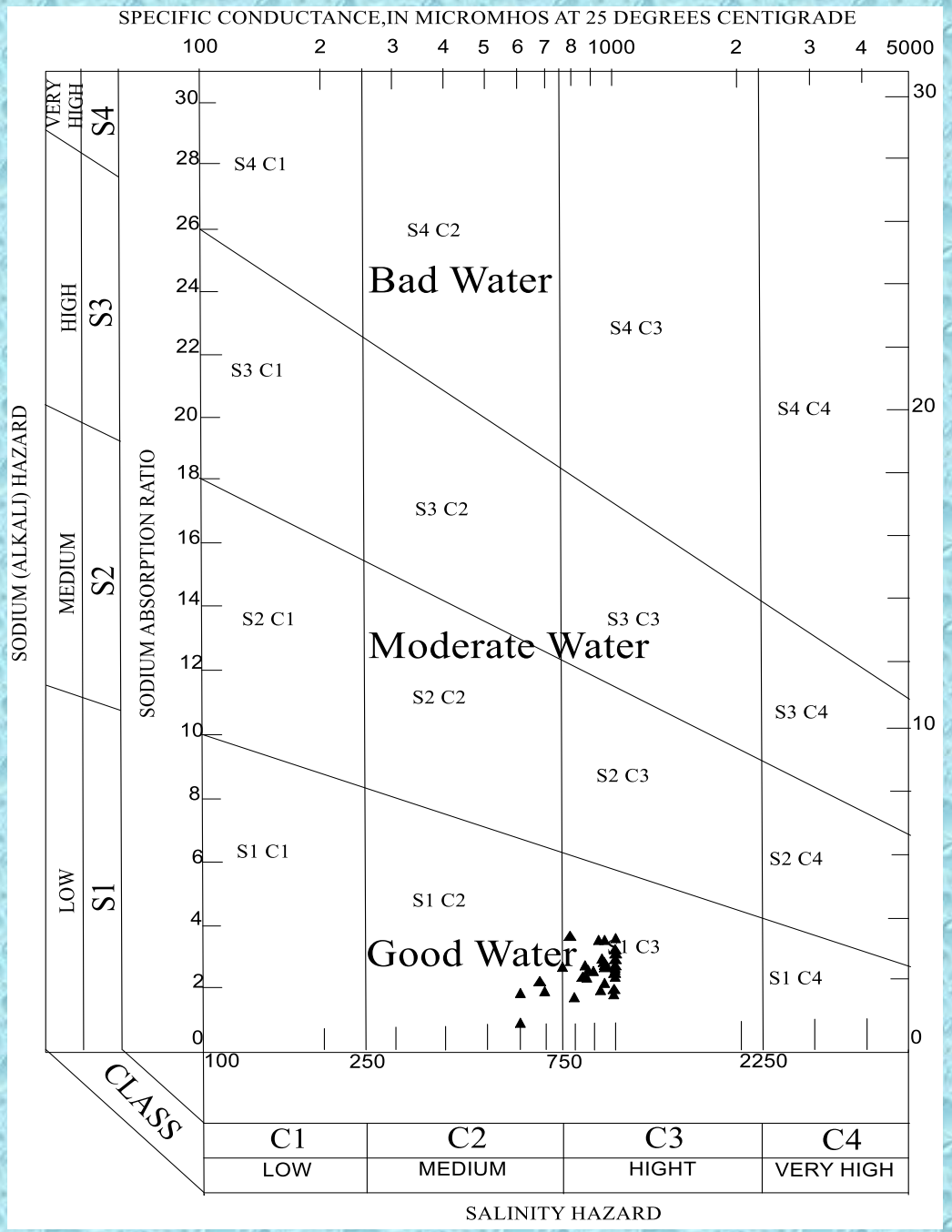
Minor Water Type Ca^{++}-Na^{+} $SO_4^{=}$-Cl^{-}

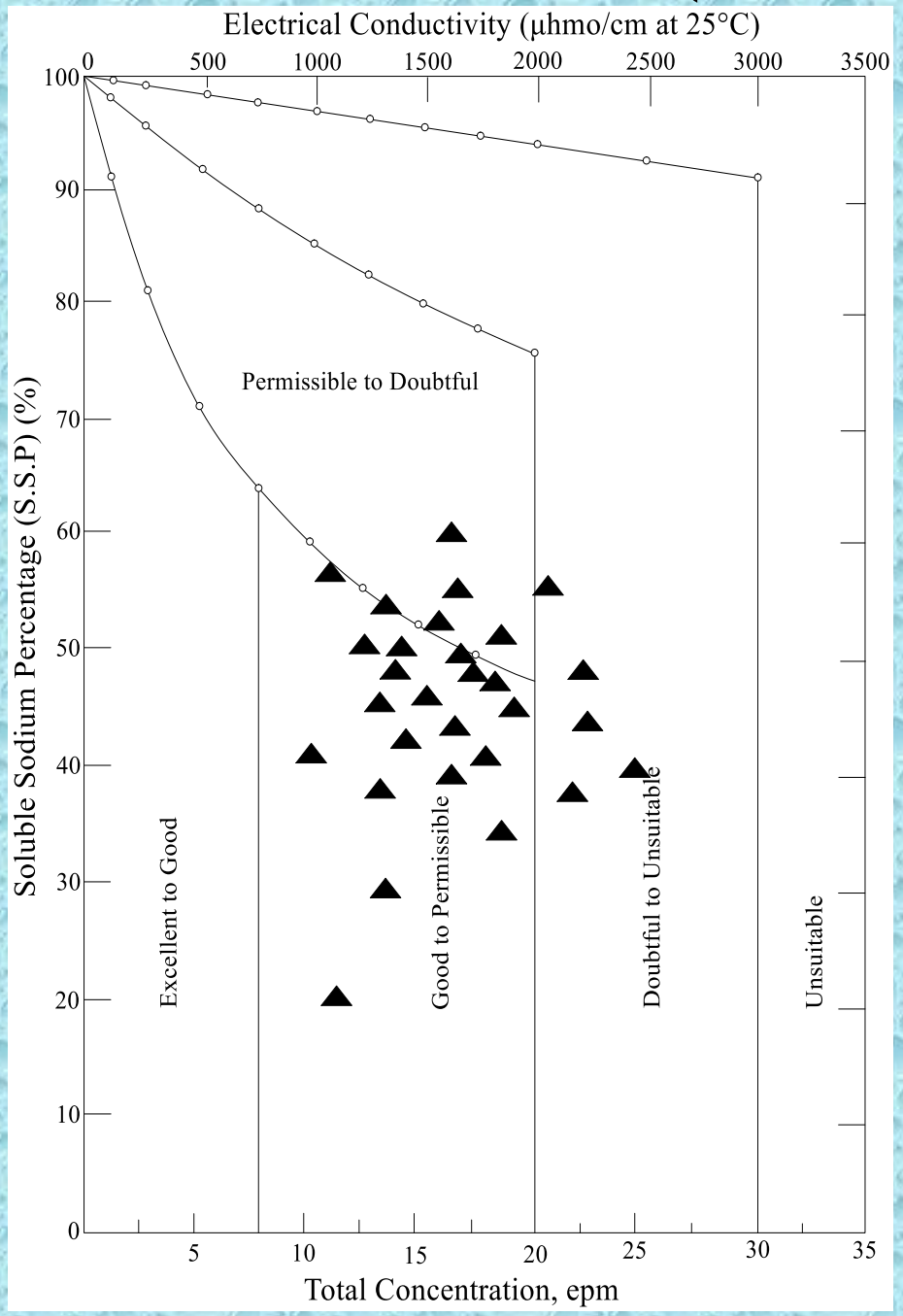
USSL diagram for classification of Irrigation water



Groundwater from Irrawadian aquifer are found to occur in classes as:

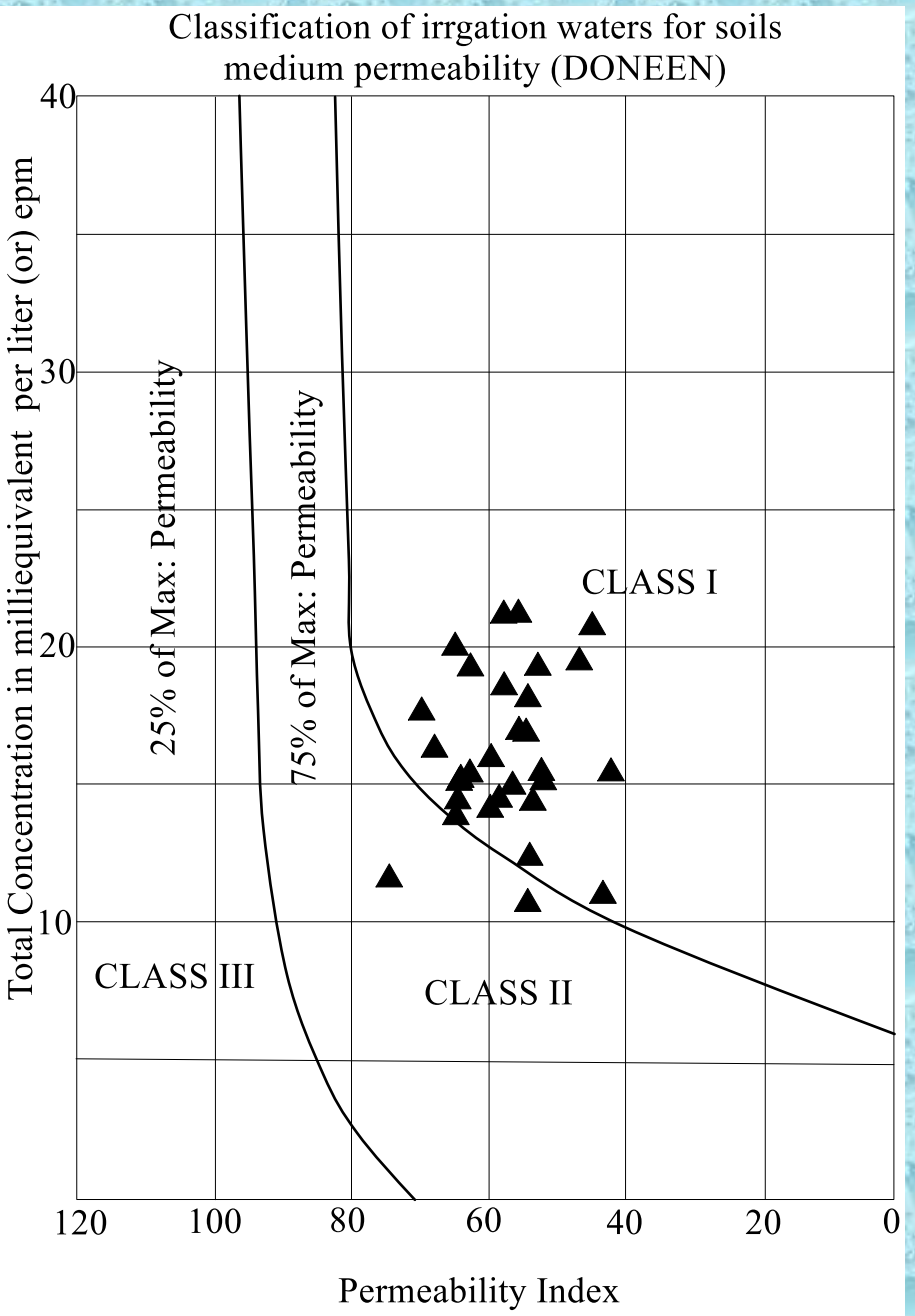
1. S_1C_2 – Low sodium hazard with medium salinity hazard
2. $S_1\ C_3$ -Low sodium hazard with high salinity hazard

Classification of groundwater for Irrigation Base on Na% (After Wilcox, 1955)



- Most of the groundwater samples are within good to permissible limit and a few samples are permissible to doubtful and doubtful to unsuitable

Possible Utilization of Groundwater for Irrigation by Permeability Index



Most of the groundwater samples fall under Class I.
Well no. 3/27 and 3/29 fall Class II.
Class I and Class II are suitable for Irrigation.

Summary Statistics of different indices of groundwater for irrigation (Irrawaddian aquifer)

Parameter	Minimum	Maximum	Mean
SAR	0.87	3.74	2.5
SSP (%)	23	56	44
RSBC (meq/L)	-3.31	0.08	-1.40
PI (%)	41	74	57
MAR (%)	22	68	41
KR	0.3	1.3	0.8
EC µmhos/cm	600	1000	896
TDS (mg/L)	390	650	582

Limits of some parameter indices for rating groundwater quality and its sustainability in irrigation (Ayers and Westcot, 1985;Eaton, 1950; Wilcox, 1950)

Category	EC µmhos/cm	TDS (mg/L)	RSBC (meq/L)	SSP (%)	SAR	Sustainability for Irrigation
I	< 250	0 – 1,000	<1.25	<20	<10	Excellent
II	250-750	1,000 – 10,000	1.25-2.5	20-40	10-18	Good
III	750-2250	10,000 – 100,000	>2.5	40-80	18-26	Fair
IV	2250->4000	More than 100,000	-	>80	>26	Poor

Allowable Unit		
Parameter	Minimum	Maximum
SSP (%)	<20	80
RSBC (meq/L)	1.25	2.5
MAR (%)	7.97	50
KR	0	1

Potential Salinity (PS) in Irrawaddian Aquifer (Doneen, 1964)

❖An important parameter "Potential Salinity" (PS) for assessing the suitability of water quality for irrigation.

❖Excessive salinity occurs when there is an accumulation of salts in top soils.

❖Soil permeability can be reduced by the built up of salts.

❖Crop production is reduced.

$$PS = Cl + 1/2\ SO_4 \text{ Unit (meq/l)}$$

The allowable unit of Potential Salinity (PS) is<1.5 to 5. The PS value of the Younger Alluvial Aquifer is ranging from 1.2 to 4.7 meq/L. So, it is suitable for irrigation.

Summary Statistics of different indices of groundwater for irrigation (Younger Alluvial Aquifer)

Parameter	Minimum	Maximum	Mean
SAR	1.76	5.25	3.45
SSP (%)	30.73	64	44.8
RSBC (meq/L)	-4.3	1.2	-1.34
PI (%)	44	78	64
MAR (%)	24	51	38
KR	0.45	1.6	1
EC µmhos/cm	1350	2100	1592
TDS (mg/L)	877	1365	1034

Limits of some parameter indices for rating groundwater quality and its sustainability in irrigation (Ayers and Westcot, 1985;Eaton, 1950; Wilcox, 1950)

Category	EC µmhos/cm	TDS (mg/L)	RSBC (meq/L)	SSP (%)	SAR	Sustainability for Irrigation
I	< 250	0 – 1,000	<1.25	<20	<10	Excellent
II	250-750	1,000 – 10,000	1.25-2.5	20-40	10-18	Good
III	750-2250	10,000 – 100,000	>2.5	40-80	18-26	Fair
IV	2250->4000	More than 100,000	-	>80	>26	Poor