WHAT'S IN YOUR WATER WELL?

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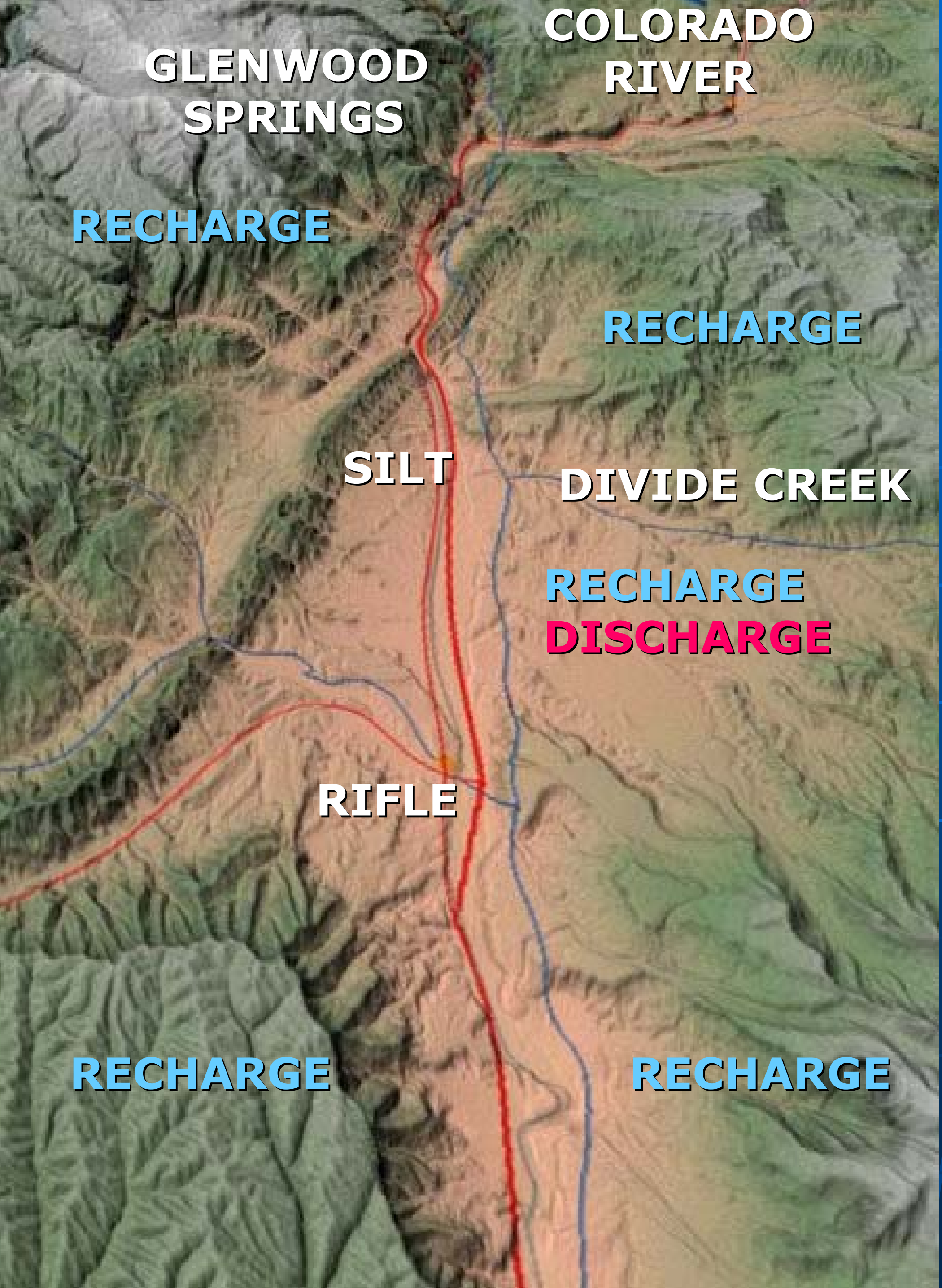
WHAT'S IN YOUR WATER WELL?

INTERPRETING LABORATORY DATA

- WHERE DOES YOUR WATER COME FROM?
- WHAT CONSTITUENTS ARE DISSOLVED IN GROUNDWATER?
- WHAT FACTORS CONTROL THE CONCENTRATION OF DISSOLVED CONSTITUENTS?
- REGULAR MAINTENANCE OF YOUR WATER WELL
  - **WHAT TO LOOK FOR**
  - **WHAT TO DO**



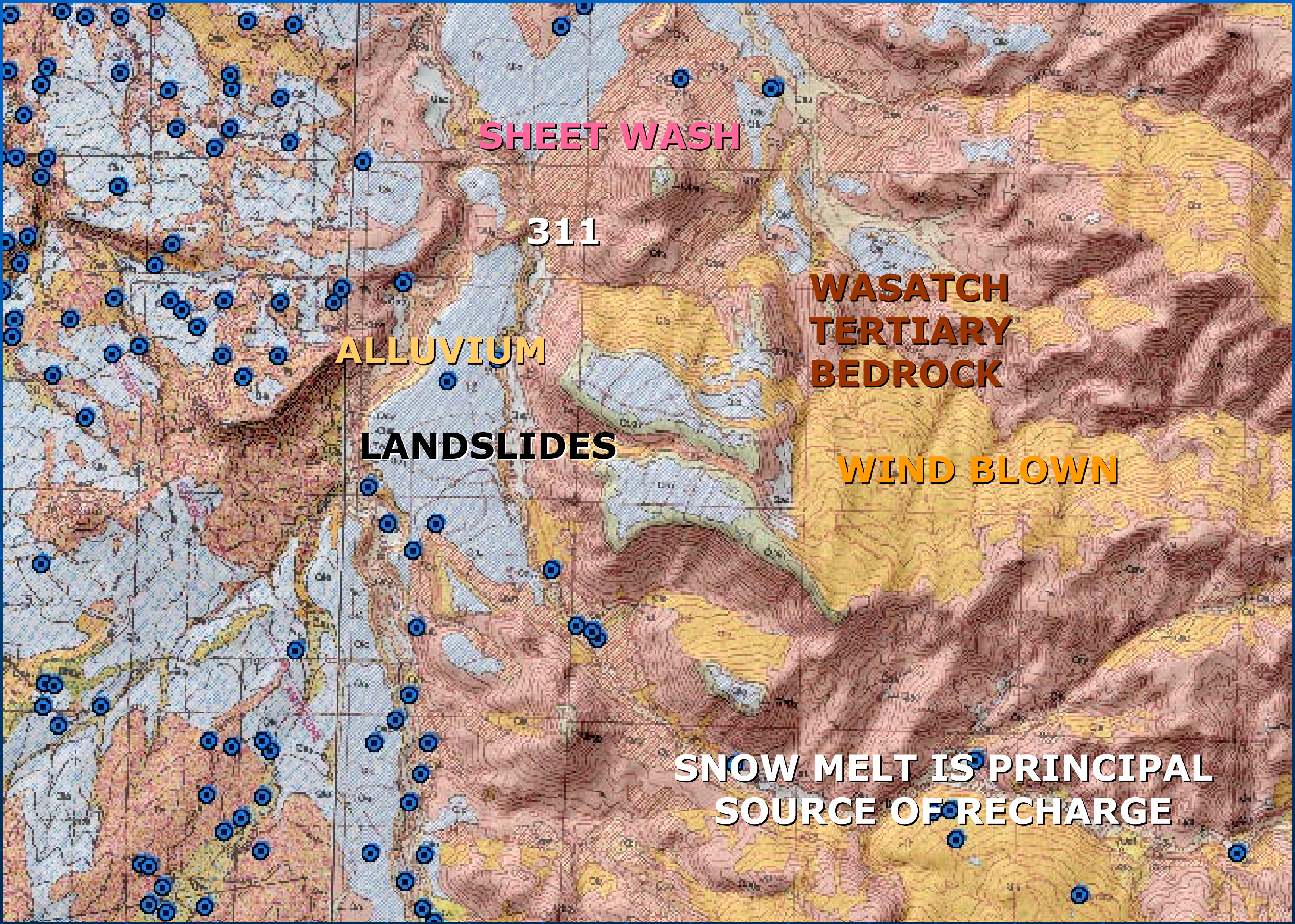
WHERE DOES YOUR WATER COME FROM?

PHYSIOGRAPHIC SETTING

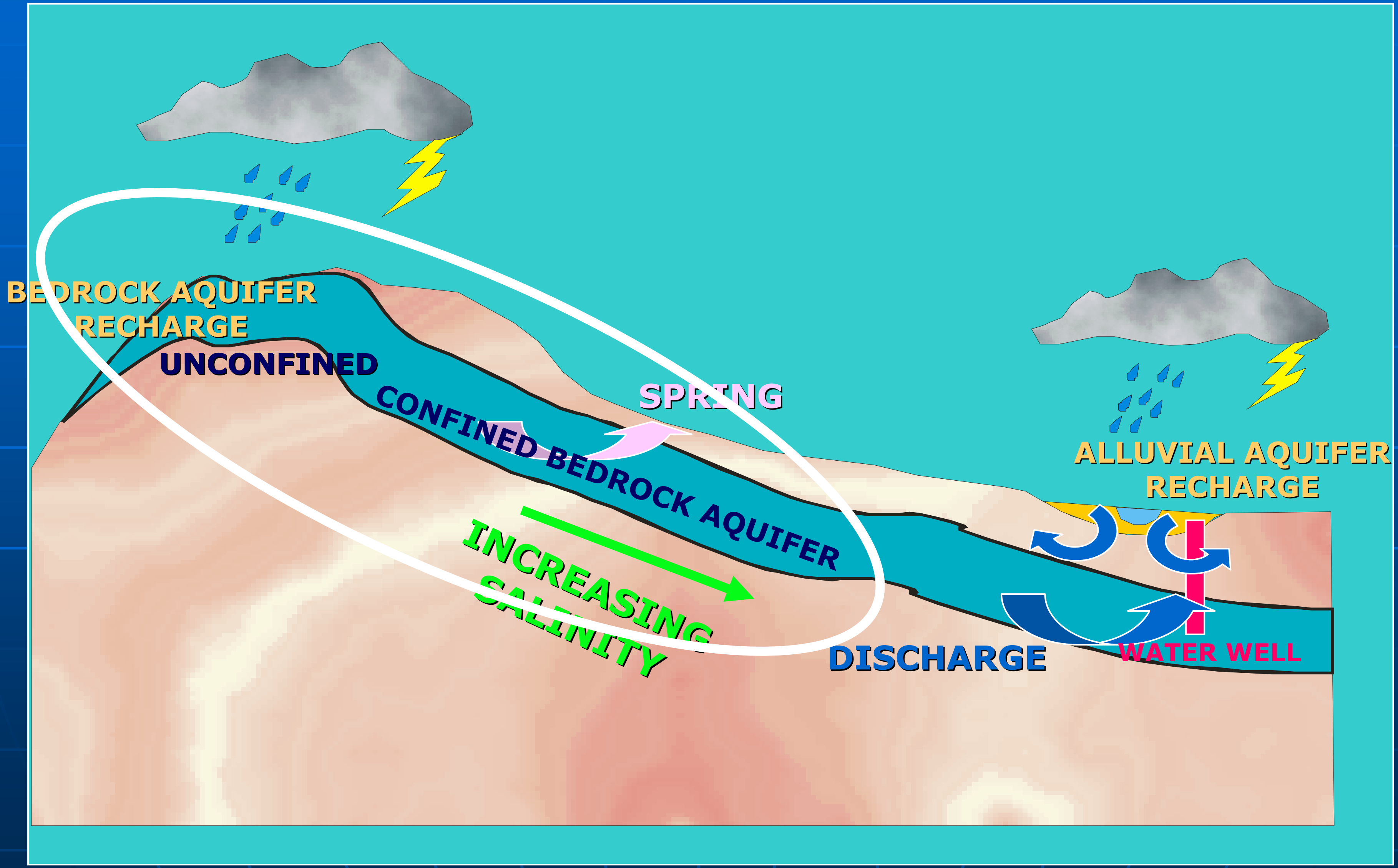
AQUIFERS TYPES

- ALLUVIAL
- BEDROCK

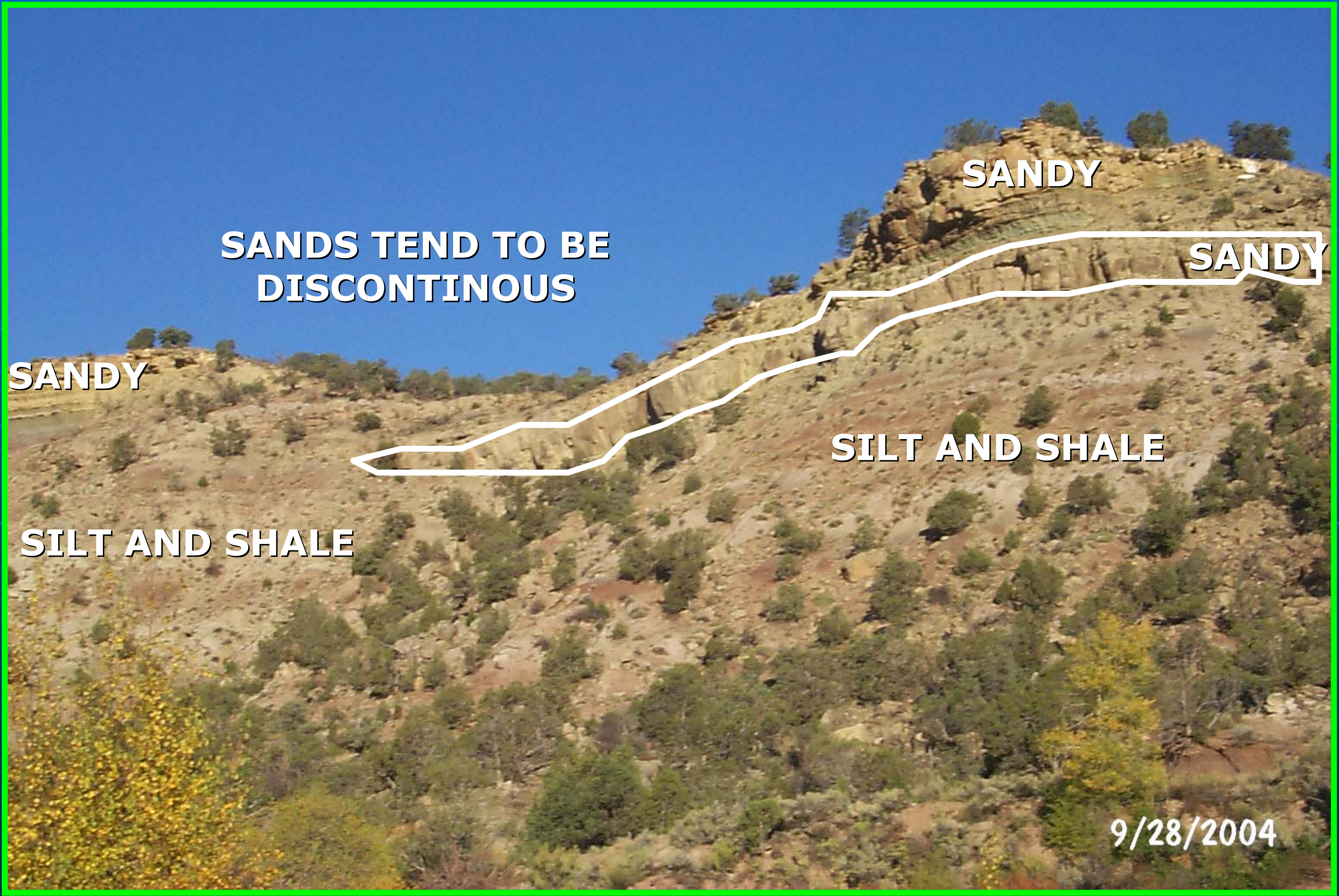
TYPICAL GEOLOGIC MAP HUNTER MESA AND GIBSON GULCH QUADRANGLES AND WATER WELLS



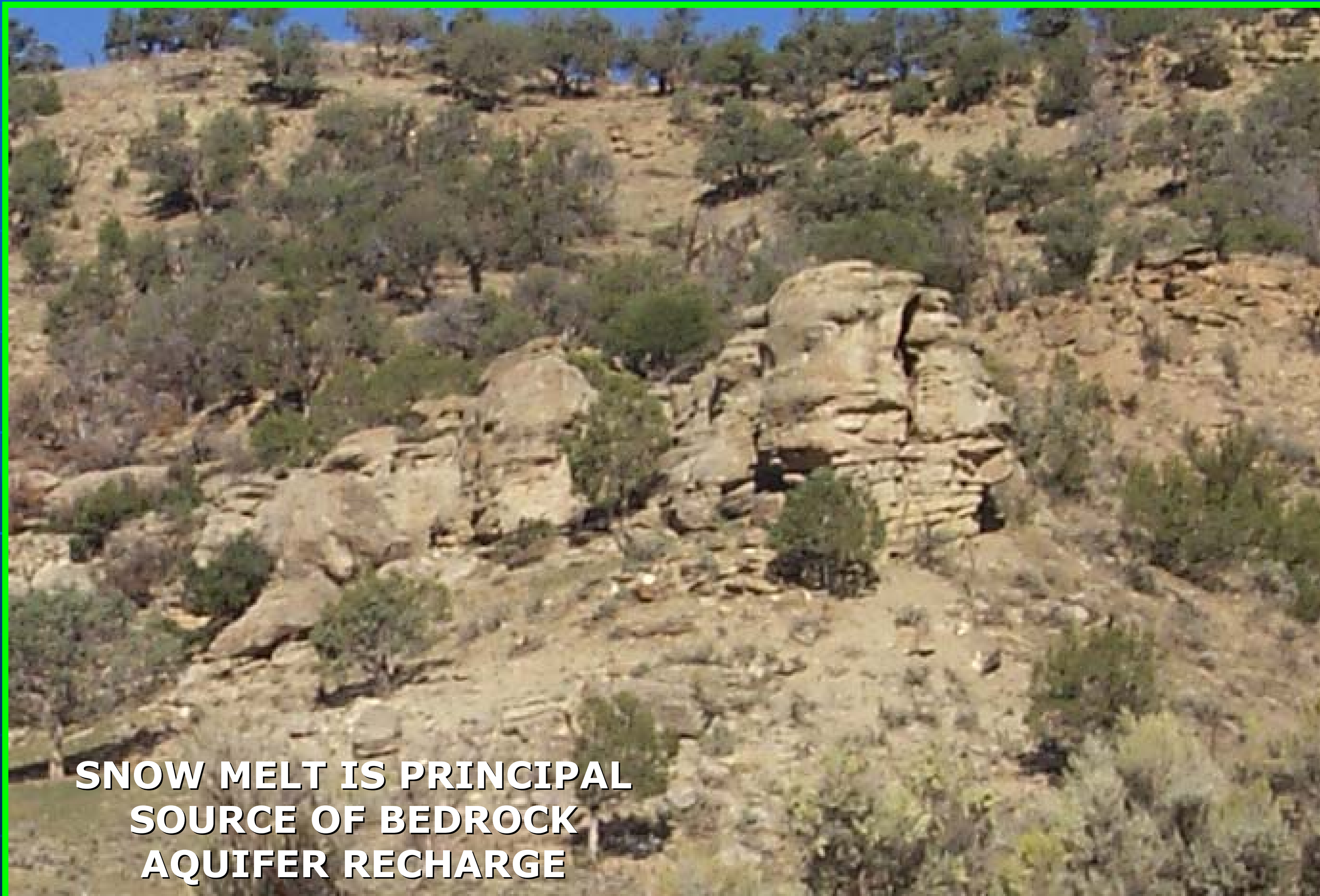
IDEALIZED AQUIFER RECHARGE AND DISCHARGE



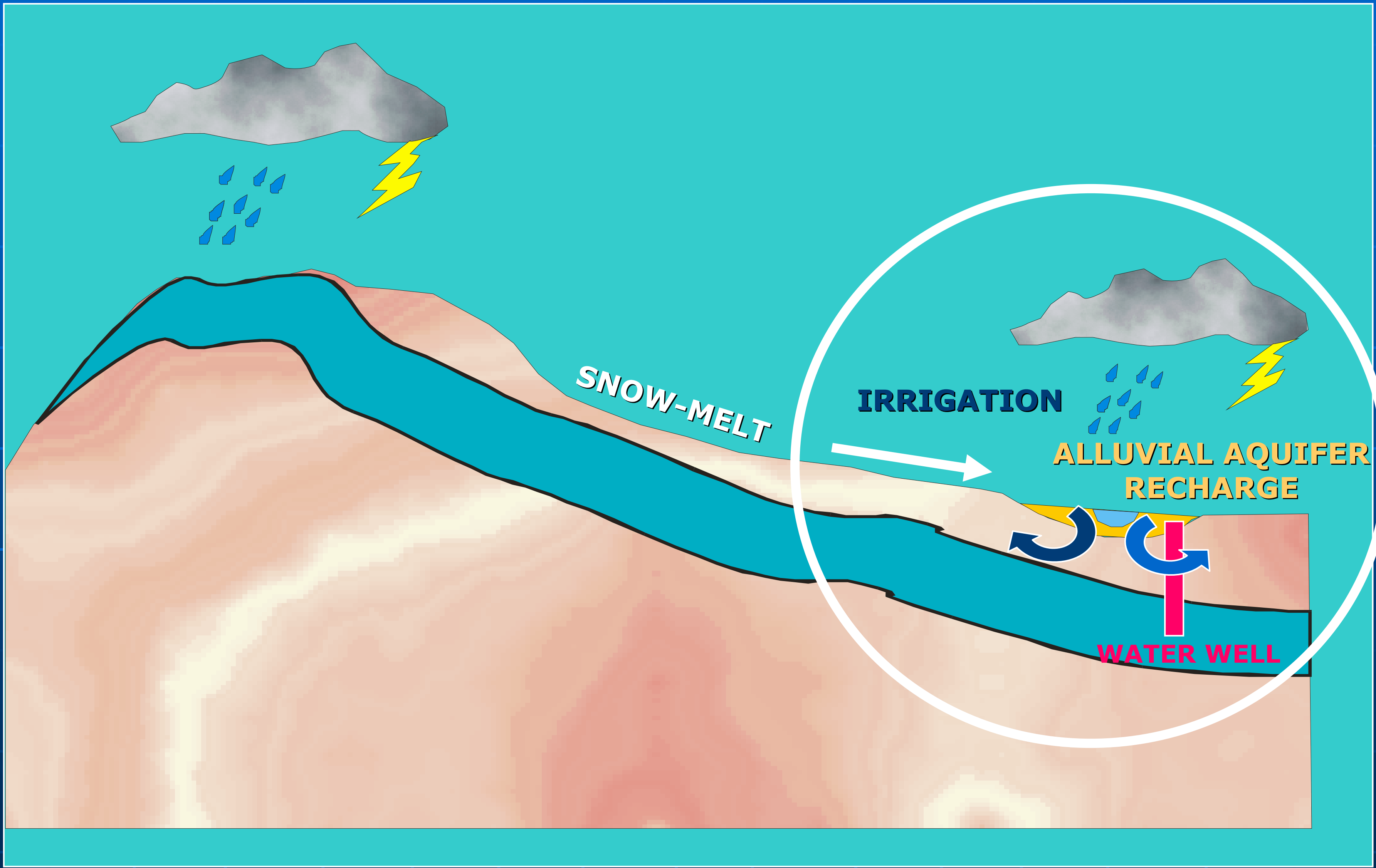
BEDROCK AQUIFERS ARE DISCONTINUOUS



GROUNDWATER FLOW IN BEDROCK FUNNELED BY DISCONTINUOUS SWARMS OF NATURAL FRACTURES



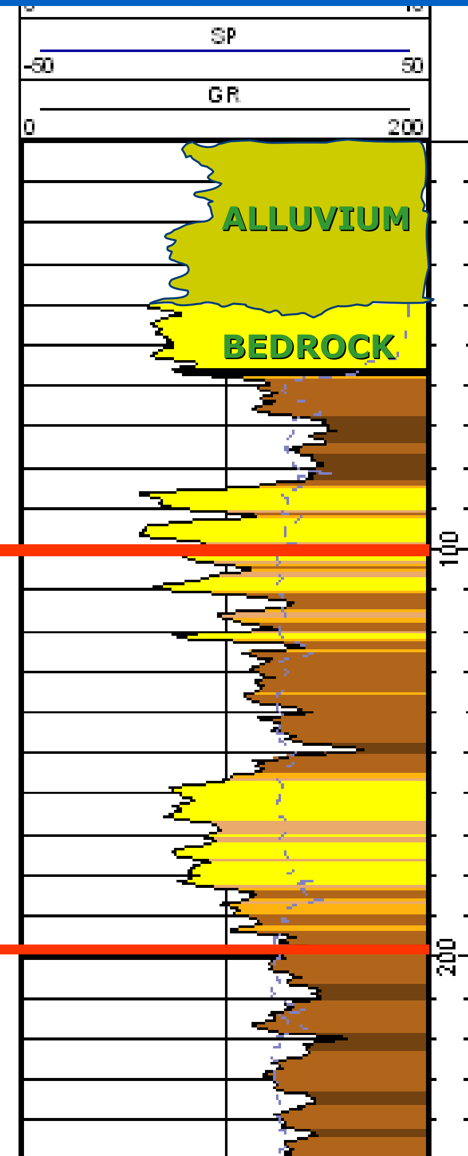
IDEALIZED AQUIFER RECHARGE AND DISCHARGE



TYPICAL ALLUVIAL AQUIFERS: DIVIDE CREEK NARROW VALLEY FILL

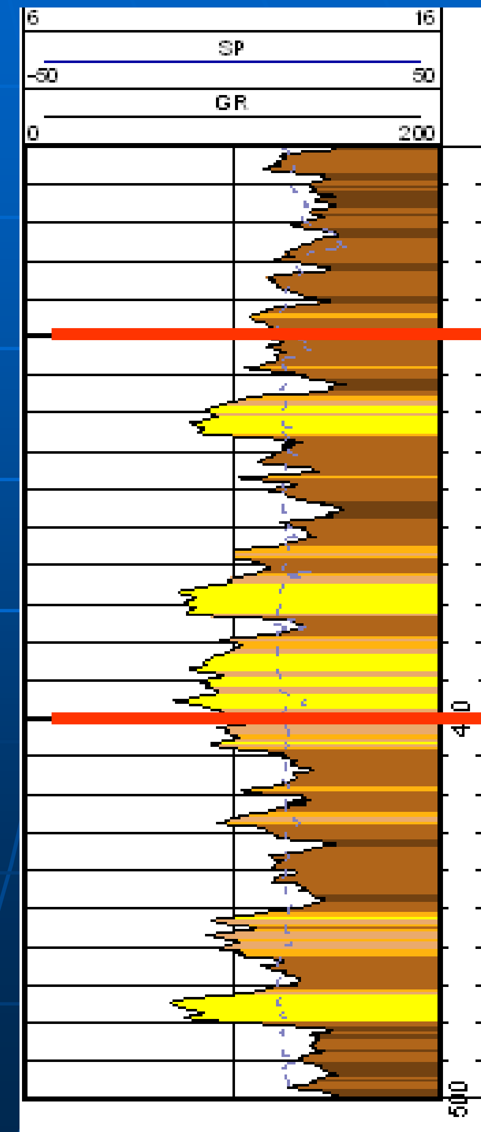
TYPICAL ALLUVIAL AQUIFER TEXTURE

GAMMA RAY TRACES OF SHALLOW SUBSURFACE SHOW POTENTIAL AQUIFERS

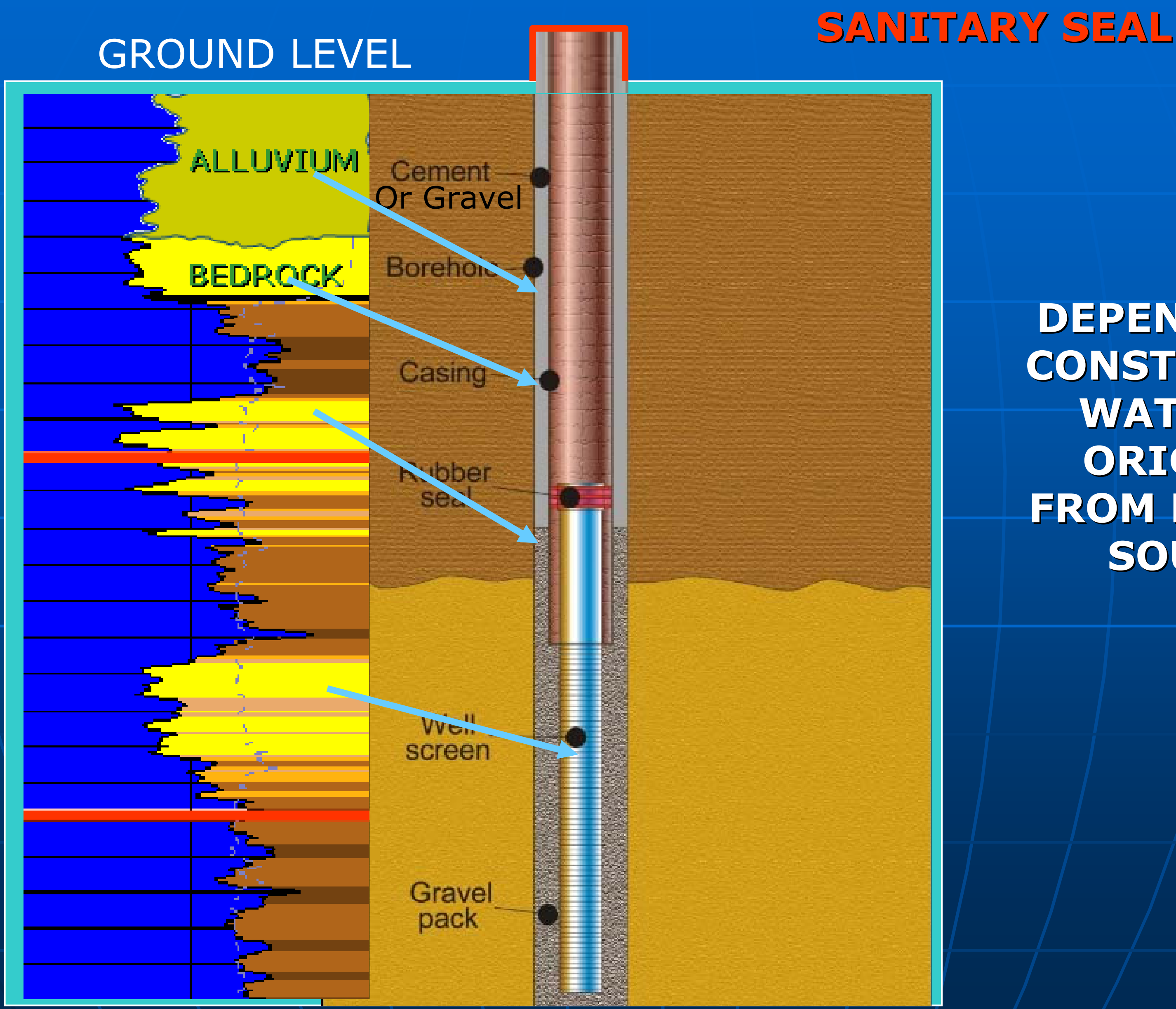


- SAND
- SILTY SAND
- SILTY SHALE
- SHALE

EACH SAND MAY OR MAY NOT PRODUCE WATER



TYPICAL WELL BORE CONSTRUCTION



DEPENDING ON CONSTRUCTION, WATER CAN ORIGINATE FROM MULTIPLE SOURCES

WELLS MUST BE PROPERLY CONSTRUCTED TO AVOID PROBLEMS WITH YIELD AND WATER QUALITY

- WHAT IS SIGNIFICANCE OF DISCOLORED PAVEMENT IN WELL HOUSE?

INTERPRETING THE SOURCE AND QUALITY OF WATER

- FIELD DATA ACQUISITION
- FIELD SAMPLE ACQUISITION
  - LABORATORY SAMPLING AND ANALYSIS
  - DISSOLVED SALTS AND MINERALS
  - DISSOLVED ORGANIC COMPONENTS
- LAB REPORTS
- INTERPRETATION

FIELD SAMPLING AND LABORATORY ANALYSIS

FIELD MEASURMENTS : WATER LEVEL, ACIDITY, CONDUCTIVITY DISSOLVED OXYGEN, TURBIDITY, SMELL, COLOR

- **SENSORS TO DETECT WATER QUALITY**
  - FLOW THROUGH
  - INDIVIDUAL
- **WATER LEVEL**

SAMPLES COLLECTED AND SENT TO LABORATORIES FOR ANALYSIS

WHAT LABORATORY DATA REPORTS CONTAIN

- **GENERAL QUALITY INDICATORS**: Total salt content (< 500 mg/L), Hardness (<180 mg/L), Turbidity (<20 NTU).
- **DISSOLVED MINERAL SALT COMPOSITION :**
- **INORGANIC HEALTH IMPURITIES**: Fluoride (< 4.0 mg/L), Selenium (< 0.05 mg/L) , Nitrates (< 10 mg/L), Nitrites (<1 mg/L),
- **ORGANIC HEALTH IMPURITIES:** BTEX - Benzene (<5 ppb), Toluene (<1 mg/L), Ethyl benzene (<700 ppb), Xylene (<10 mg/L),
- **NUISANCE CONSTITUENTS**: Iron (< 0.3 mg/L), Manganese (< 0.05 mg/L), Sulfate (< 250 mg/L), Chlorides (< 250 mg/L);
- **BACTERIA**
- **DISSOLVED NATURAL GAS**

Sample ID	Client Sample ID	Matrix	Collection Date	Date Received	Storage	Test Code	Test Name
04-7410-01A	093004-S6	Water	9/30/04	10/1/04	3	8021_W *	8021: BTEX, MtBE
04-7410-01B	093004-S6	Water	9/30/04	10/1/04	B6	6020_WT *	6020 Total Metals
04-7410-01C	093004-S6	Water	9/30/04	10/1/04	B6	SULF_H2S	Hydrogen Sulfide
04-7410-01D	093004-S6	Water	9/30/04	10/1/04	B6	COND_W	Specific Conductance @ 25°C
04-7410-01D	093004-S6	Water	9/30/04	10/1/04	B6	F_W	Fluoride
04-7410-01D	093004-S6	Water	9/30/04	10/1/04	B6	PH_W	pH
04-7410-01D	093004-S6	Water	9/30/04	10/1/04	B6	TDS_W	Total Dissolved Solids (TDS)
04-7410-01E	093004-S6	Water	9/30/04	10/1/04	B6	ANIONS_W *	Anions by IC
04-7410-01F	093004-S6	Water	9/30/04	10/1/04	B6	ALK_WGRP *	Alkalinity
04-7410-01G	093004-S6	Water	9/30/04	10/1/04	2	MEEP_W *	RSK175M: Methane
04-7410-01H	093004-S6	Water	9/30/04	10/1/04	B6	AMMON_W	Ammonia-N

DISSOLVED SALT AND MINERAL CONCENTRATIONS USED TO DEFINE ACCEPTABLE WATER QUALITY STANDARDS

Primary Drinking Standards	4.00	10	0.006	0.01	2	0.005	0.1	1.3	0.015	0.002	0.05
(mg/L)	F	NO3	Sb	As	Ba	Cd	Cr	Cu	Pb	Hg	Se

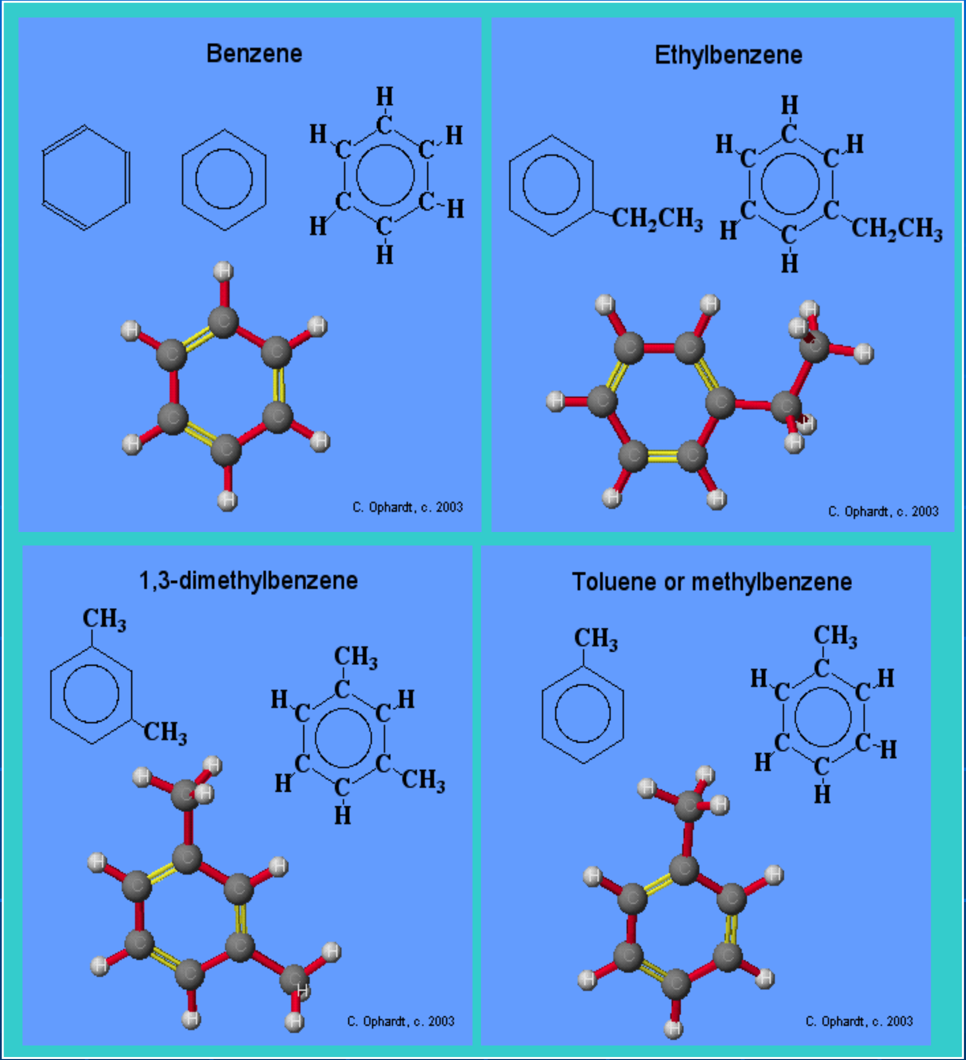
Secondary Drinking Standards	6.5-8.5	250.0	250	500.00	0.05	0.3	0.05	0.1	5
(mg/L)	FieldpH	Cl	SO4	TDS	Al	Fe	Mn	Ag	Zn

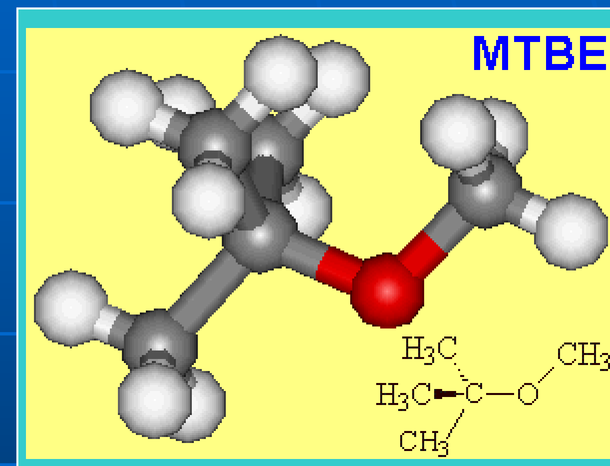
Irrigation Standards (mg/L)																
2	2000.0	2500	4.50	9	1	0.1	0.005	0.1	0.05	0.2	5	2.5	0.005	0.2	0.02	2
Mn	TDS	Ec	pH	pH	Al	As	Cd	Cr	Co	Cu	Pb	Li	Mo	Ni	Se	Zn

Stock Water Standards (mg/L)														
2000	2000	1500	1500	2.00	100	5000	0.05	0.01	1	1	0.5	0.05	0.05	24
Na	Mg	Cl	SO4	F	NO3	TDS	As	Cd	Cr	Co	Cu	Pb	Se	Zn

http://www.epa.gov/safewater/mcl.html

ANALYSES OF DISSOLVED ORGANIC CARBON COMPOUNDS: BTEX & MTBE





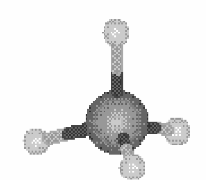
	EPA Maximum contaminant level
Benzene	*5 ppb*
Toluene	*1 ppm*
Ethylbenzene	*0.7 ppm*
Xylene	*10 ppm*

http://www.epa.gov/safewater/mcl.html

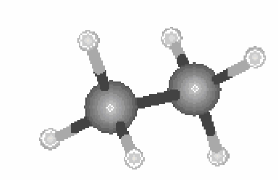
POTENTIAL CONTAMINANT SOURCES:

LEAKY FUEL TANKS
IMPROPER DUMPING
ACCIDENTAL RELEASE
OIL AND GAS WELLS

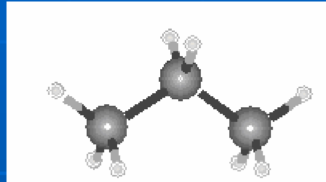
ANALYSES OF DISSOLVED ORGANIC CARBON COMPOUNDS: NATURAL GAS COMPOUNDS



Methane

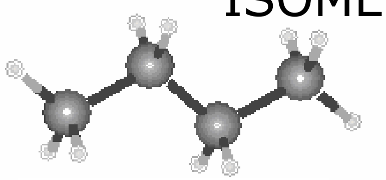


Ethane

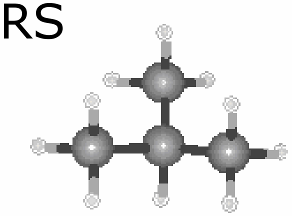


Propane

ISOMERS

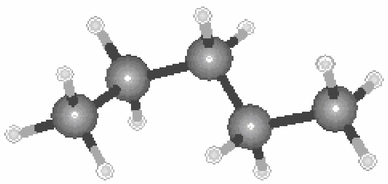


Butane

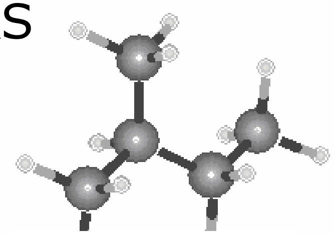


Isobutane

ISOMERS



Pentane



Isopentane

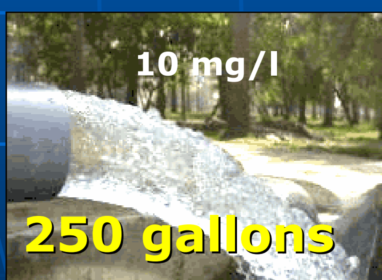
Name	State	Formula	MP degC	BP degC	Density(g/ml)
====	=====	=======	=======	=======	=======
Methane	Gas	CH_4	-183	-162	0.42
Ethane	Gas	C_2H_6	-172	-89	0.55
Propane	Gas	C_3H_8	-190	-45	0.58
Butane	Gas	C_4H_{10}	-135	-0.5	0.58
Pentane	Liquid	C_5H_{12}	-130	36	0.63
Hexane	Liquid	C_6H_{14}	- 95	69	0.66
Heptane	Liquid	C_7H_{16}	- 91	98	0.68

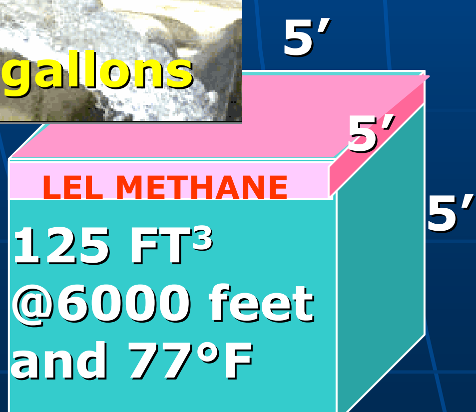
DISSOLVED GAS CONCERNS

- GASEOUS HYDROCARBONS ARE NOT TOXIC
- LIGHT HYDROCARBONS ARE SIMPLE ASPHYXIANTS
  - PROLONGED EXPOSURE TO BE AVOIDED WHEN GAS DISPLACES BREATHABLE OXYGEN
    - DIZZINESS, HEADACHES, LOSS OF JUDGEMENT:
      - METHANE 1% IN AIR
      - ETHANE: 13% IN AIR
      - BUTANE: 2% IN AIR
- LOWER EXPLOSIVE LIMIT (LEL):
  - METHANE: 5% OF AIR VOLUME
  - ETHANE: 3% OF AIR VOLUME
  - PROPANE: 2.12 % OF AIR VOLUME
  - BUTANE: 1.6% OF AIR VOLUME

WHY MONITOR DISSOLVED METHANE CONCENTRATIONS?

- **< 2 mg/L : below threshold for exsolution, concentration too low for forensic analysis**
- **> 10 mg/L : can concentrate to LEL if allowed to accumulate in unventilated spaces**
- **22 mg/L : approximate saturation concentration at 7000 feet above sea level ; effervescent**





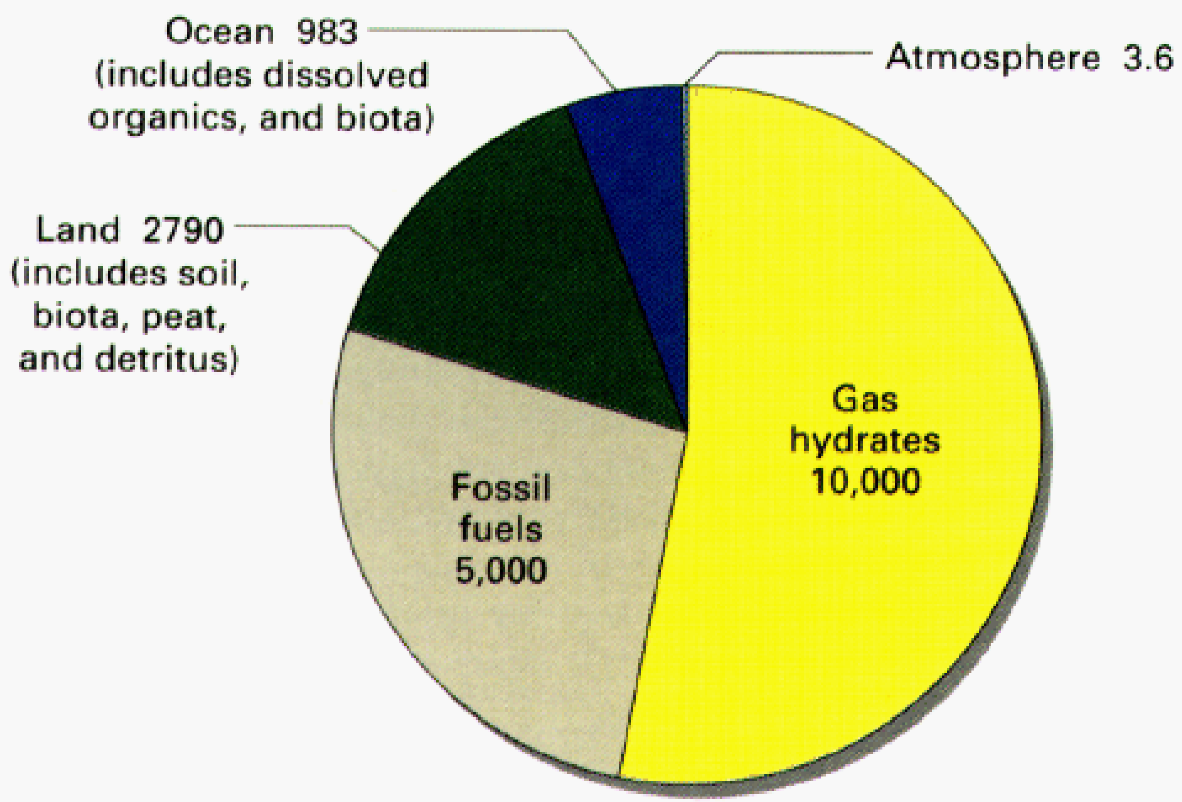
CONFINEMENT WITHOUT VENTILATION

EQUIVALENT TO AN 80 HOUR SHOWER

SOURCES OF NATURAL GAS

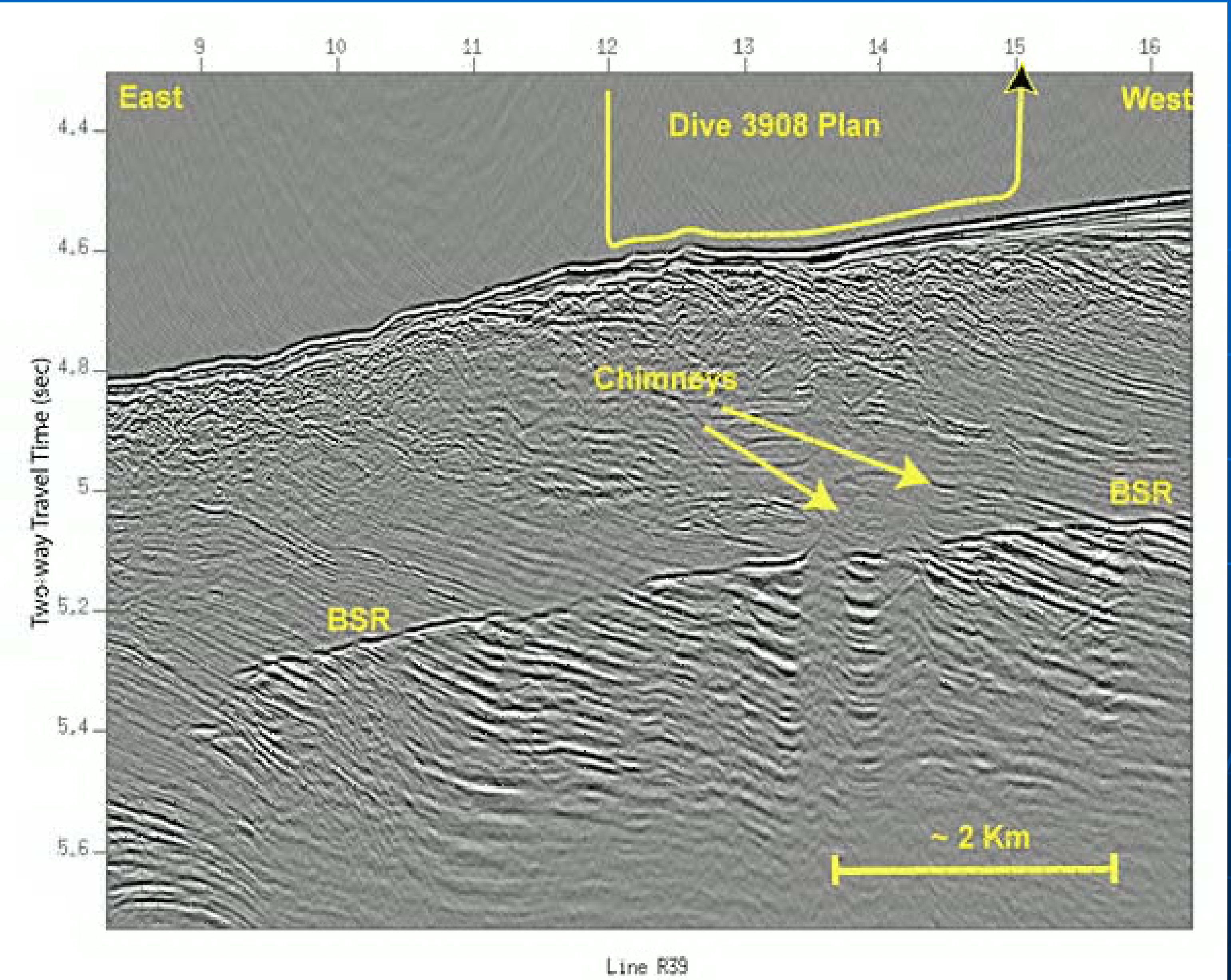
- NATURAL
  - THERMOGENIC
    - PRESSURE COOKING OF RAW ORGANIC MATERIAL DURING BURIAL
    - PETROLEUM SOURCE
      - ASSOCIATED WITH OIL
      - MIGRATED FROM OIL
      - SECONDARY CRACKING OF OIL
  - MICROBIAL
    - MARSH AND LANDFILL GAS: BACTERIAL FERMENTATION REACTIONS
    - GROUNDWATER GAS: REDUCTION OF CARBON DIOXIDE
  - ABIOGENIC
    - POLYMERIZATION REACTIONS
- CONTAMINANT
  - ACCIDENTAL OIL AND GAS WELL EMISSIONS
  - ACCIDENTAL PIPELINE EMMISSIONS
  - LAND FILLS
  - LIVESTOCK FARMING

BULK OF EARTH'S NEAR SURFACE ORGANIC CARBON LOCKED UP AS MICROBIAL METHANE IN ICE

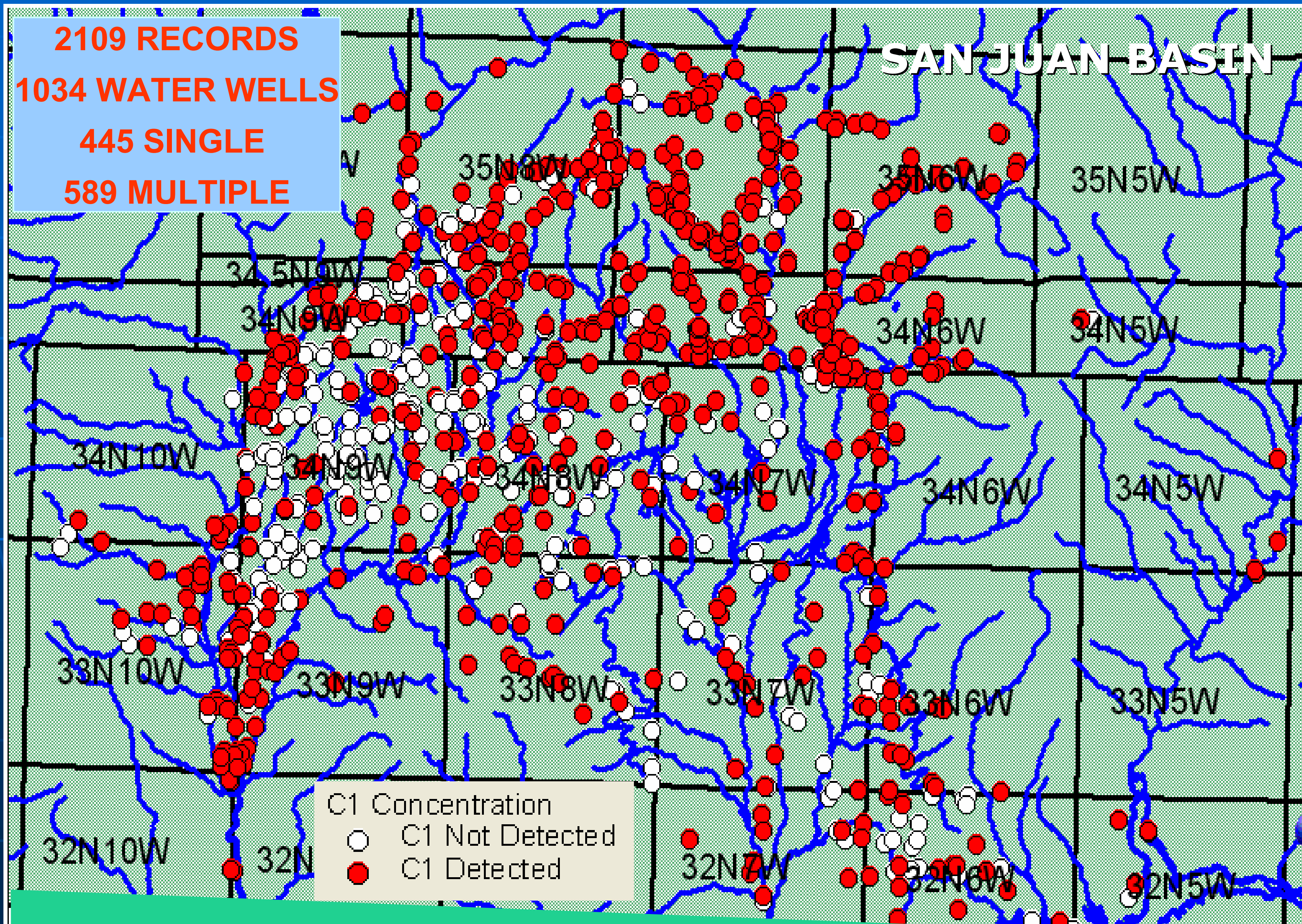


Distribution of organic carbon in Earth reservoirs (excluding dispersed carbon in rocks and sediments, which equals nearly 1,000 times this total amount). Numbers in gigatons (10^{15} tons) of carbon.

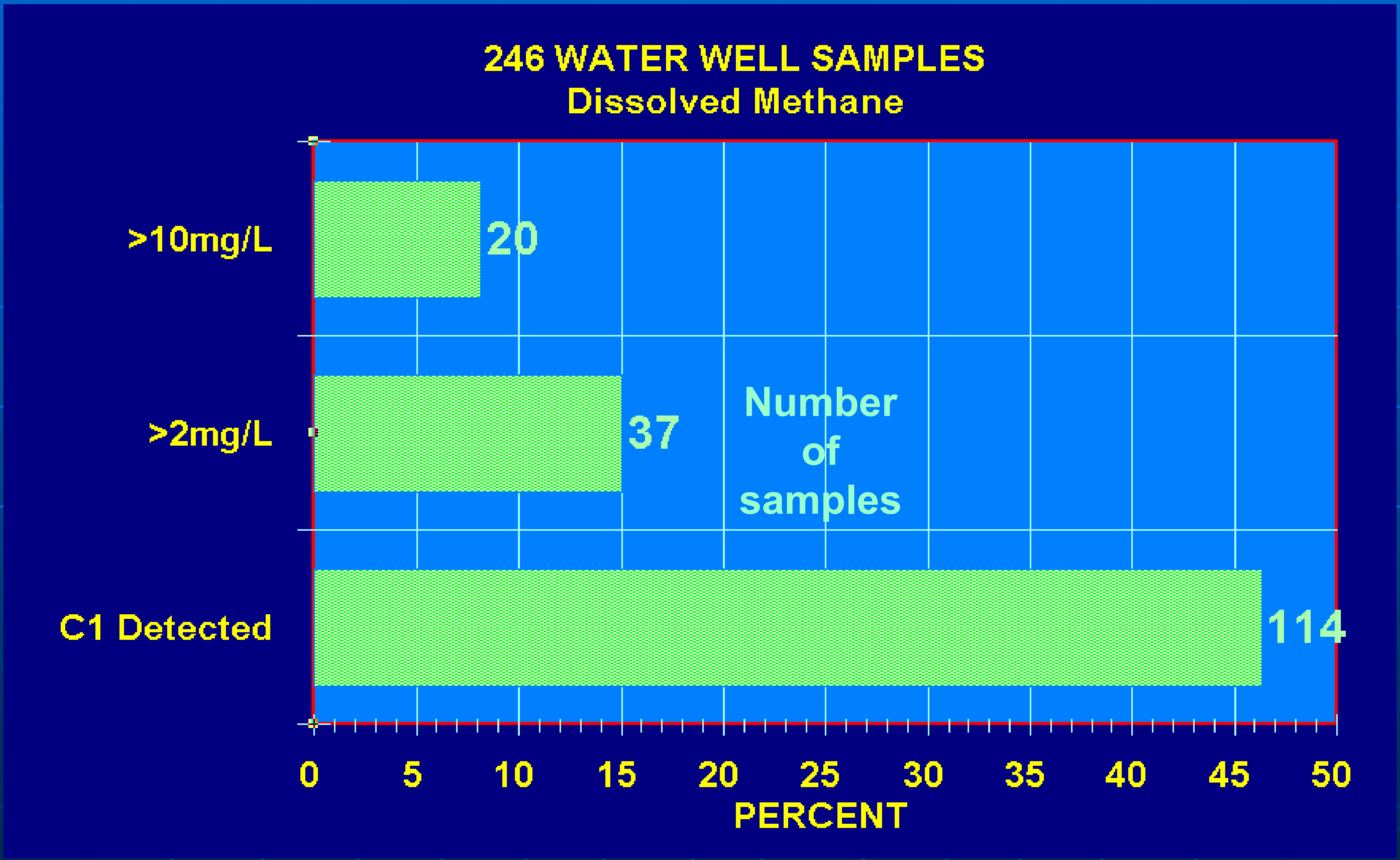
MICROBIAL METHANE LOCKED IN OCEANIC ICE DEPOSITS (HYDRATES)

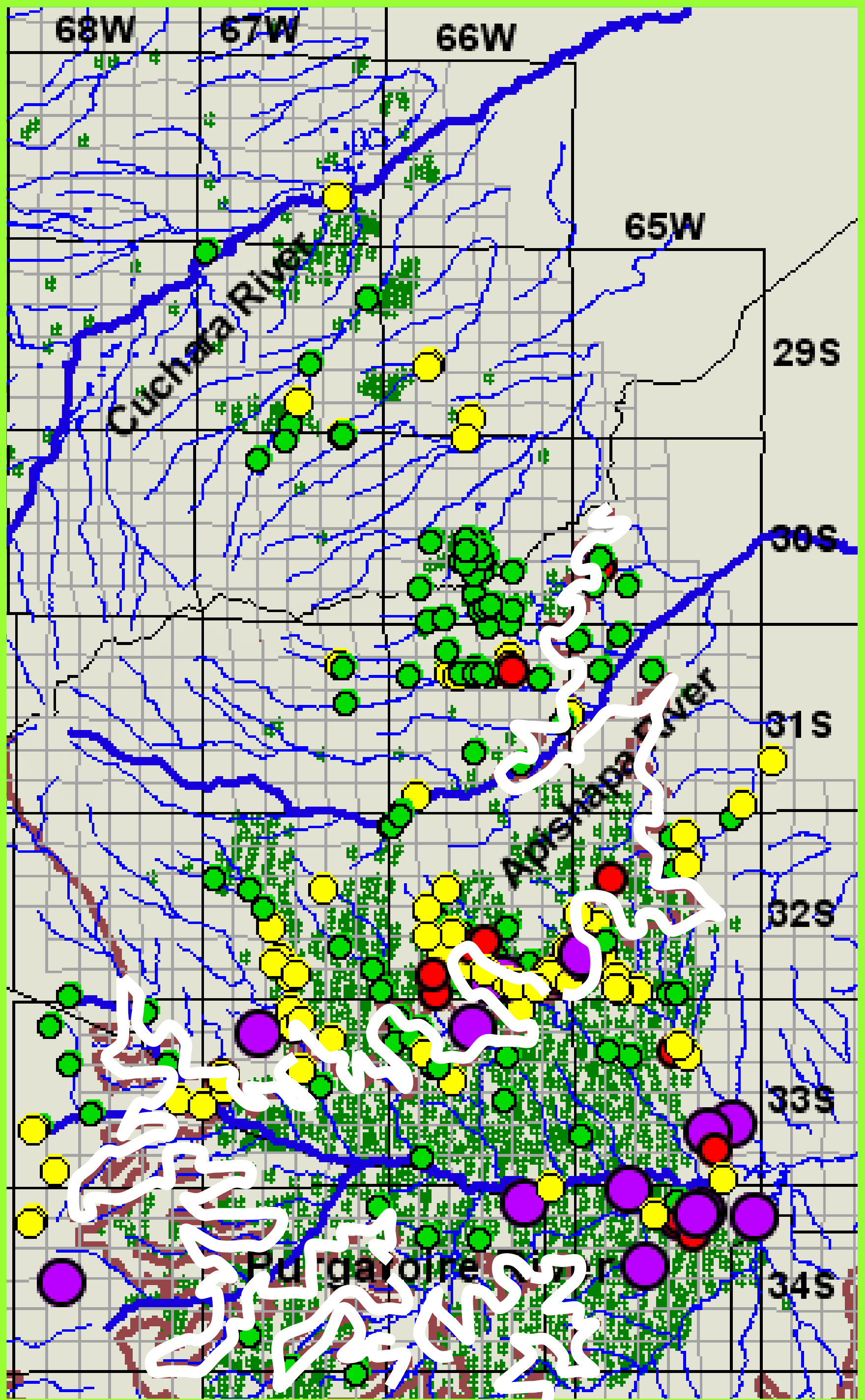


65% OF ALL SITES SAMPLED IN THE SAN JUAN BASIN CONTAIN MEASURABLE AMOUNTS OF DISSOLVED MICROBIAL METHANE



DISSOLVED METHANE IN GROUNDWATER, RATON BASIN BOTH MICROBIAL AND ASSOCIATED WITH COAL





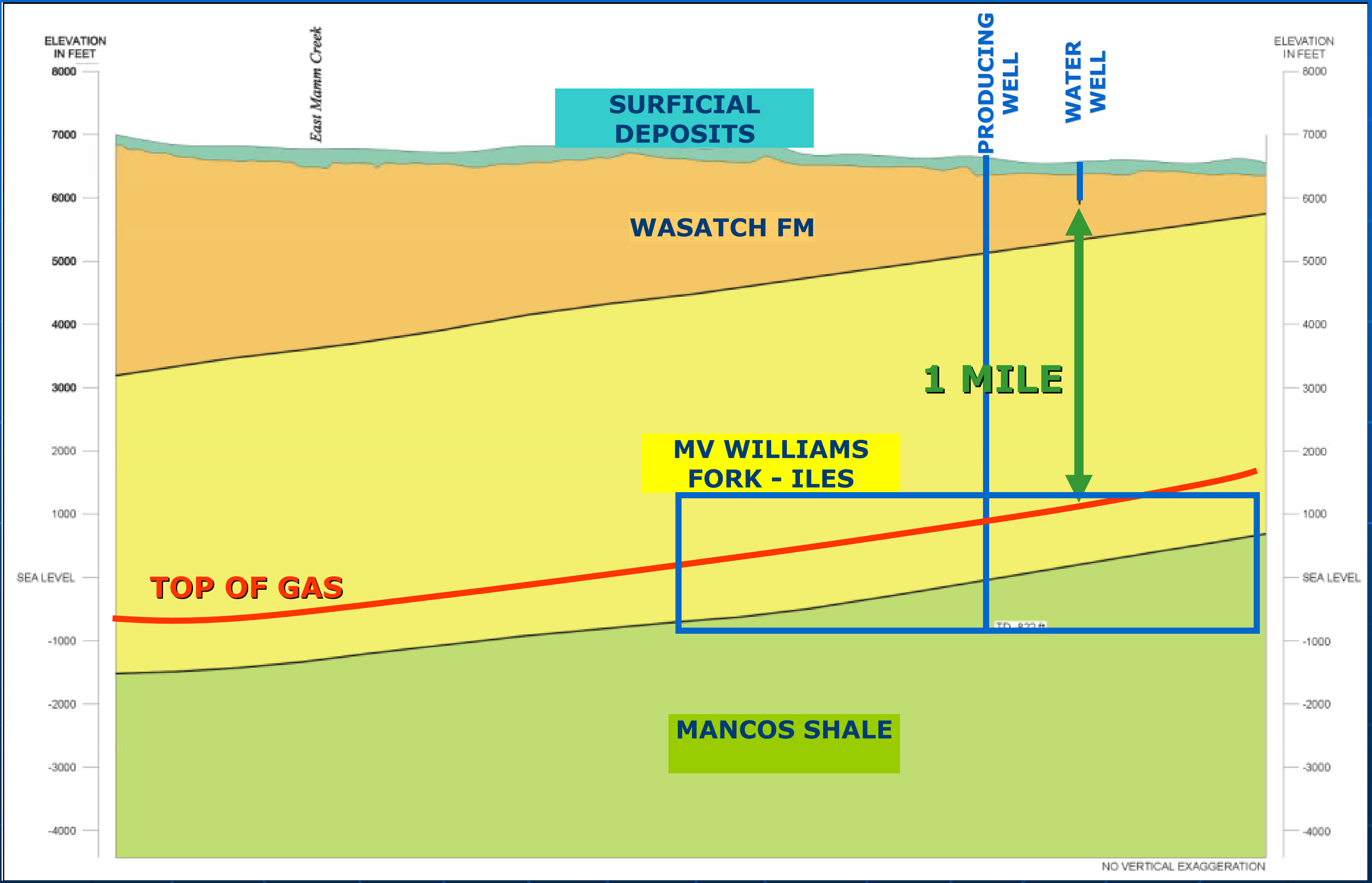
DISSOLVED METHANE FROM SHALLOW COAL OUTCROP

Dissolved Methane
- Not Detected
- Up to 2 mg/L
- 2-10 mg/L
- 10 - 38 mg/L

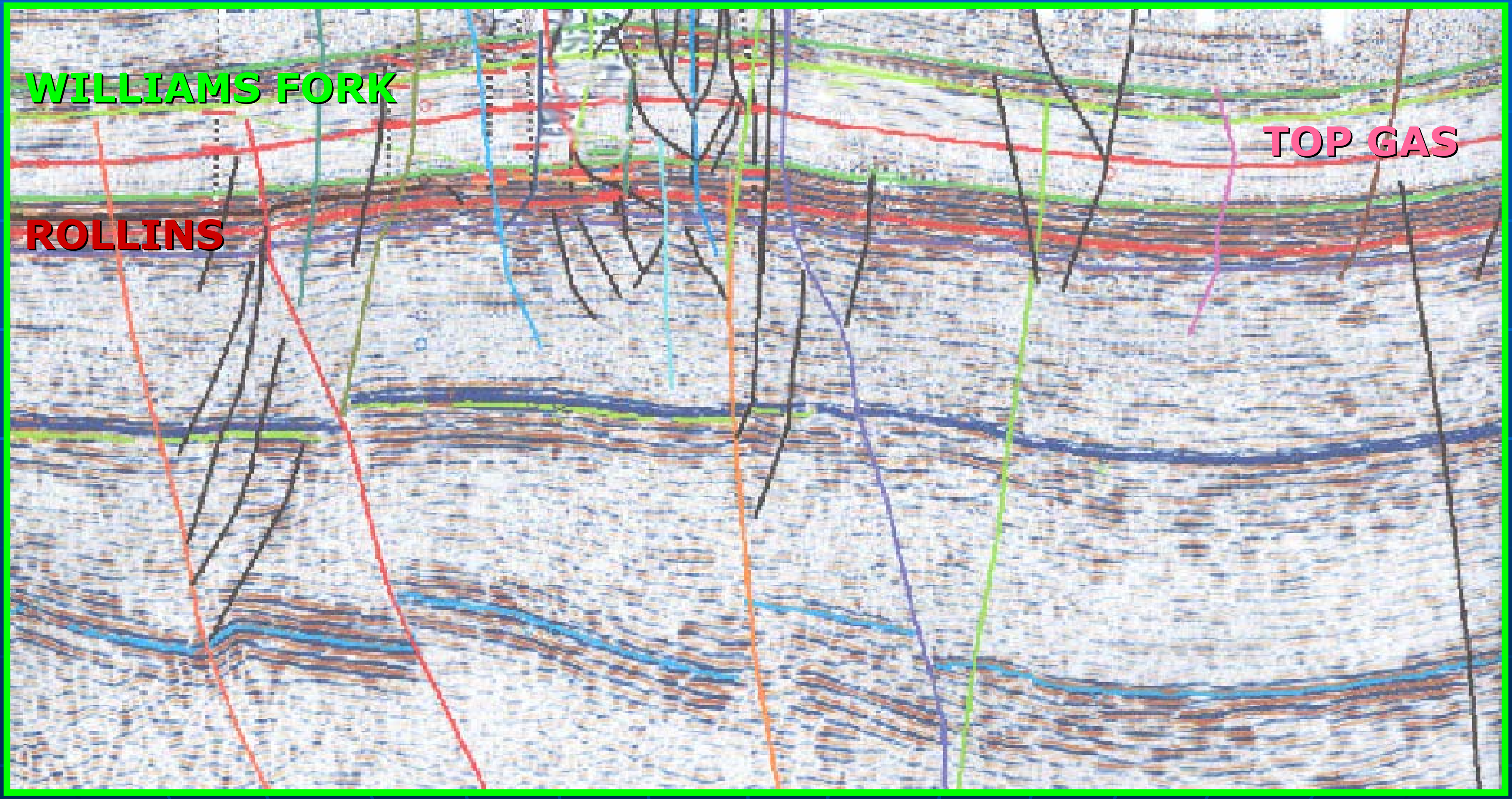
Producing Wells

Cuchara -Poison Canyon contact

THERMOGENIC GAS FROM PRODUCING INTERVAL IN PICEANCE BASIN NOT CLOSE TO SURFACE



GEOLOGIC STRUCTURE ON SEISMIC LINE SHOWING LOCALIZED FOLDING AND FAULTING



HOW DO WE CHARACTERIZE GAS SOURCES ?

DETECTING METHANE WITH A HAND HELD DETECTOR

ANALYZING GAS WITH A CHROMATOGRAPH

IN THE FIELD

IN THE LABORATORY

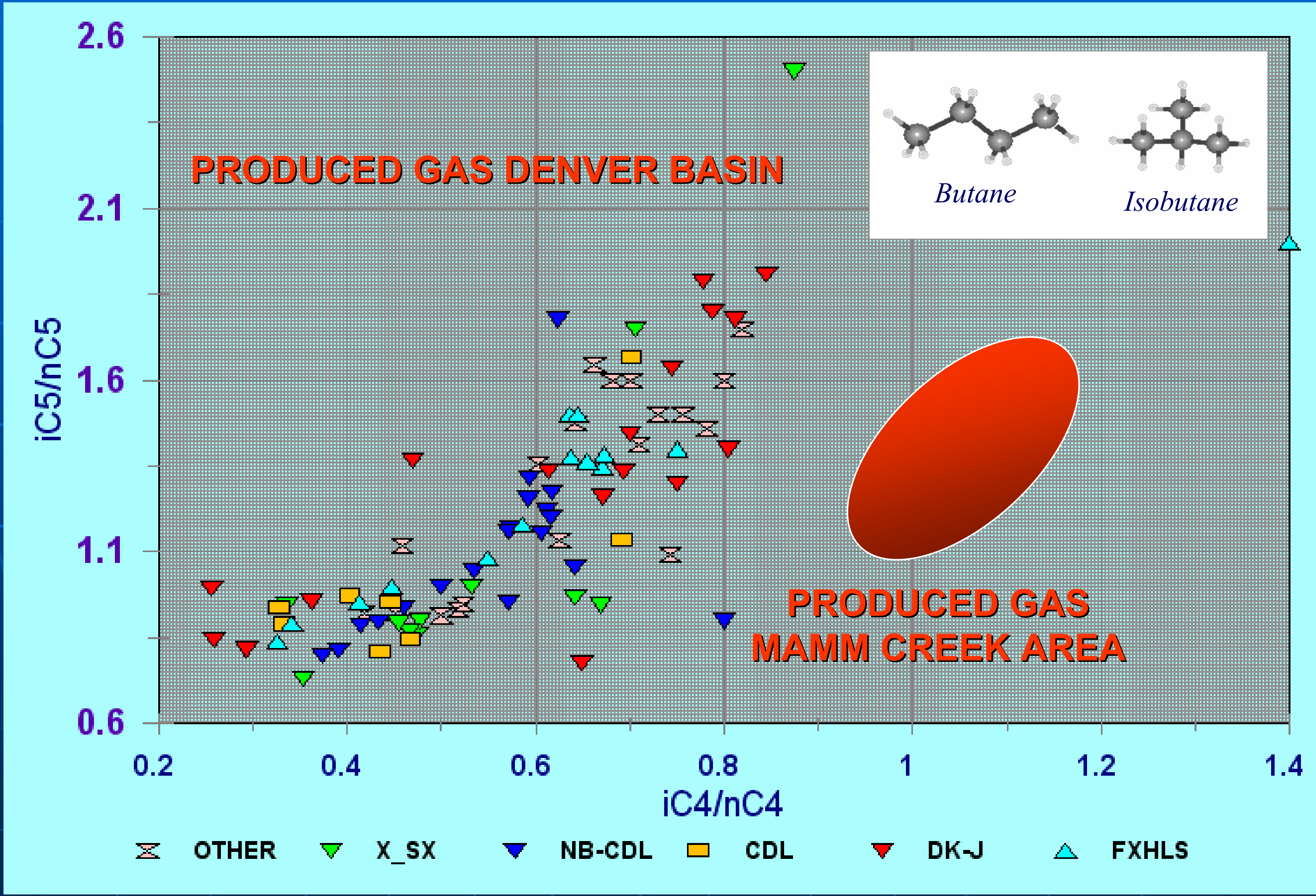
SAMPLING FOR DISSOLVED GAS CONCENTRATION AND COMPOSITION

FINGERPRINTING GAS SOURCES

COMPOSITION

- **NON HYDROCARBONS: N_2, Ar, O_2, CO_2, H_2S, He, H_2**
  - **GAS RATIOS**
    - **Relative abundance of non-hydrocarbons to hydrocarbons**
- **HYDROCARBONS: C_1, C_2, C_3, nC_4, iC_4, nC_5, iC_5**
  - **GAS RATIOS**
    - **Relative abundance of hydrocarbons**
  - **STABLE ISOTOPES**
    - **Carbon**
    - **Deuterium**

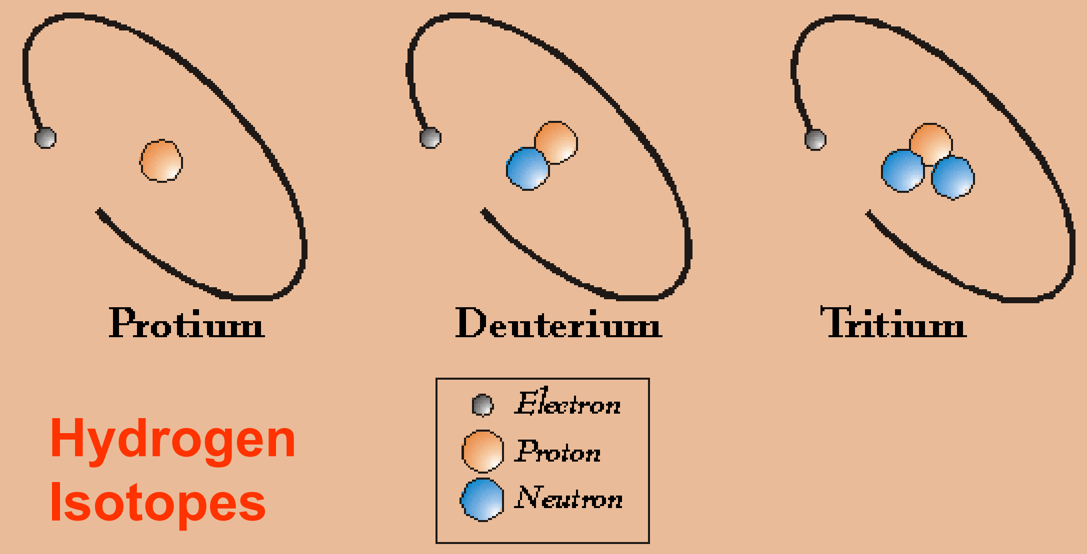
GAS RATIOS HELP TO DEFINE THE ORIGIN OF PRODUCED GAS:



STABLE ISOTOPE FINGERPRINTING

STABLE ISOTOPES ARE USEFUL TOOLS
USED TO DETERMINE THE ORIGIN OF FLUIDS AND GASES.

Many elements can exist in different forms known as isotopes. They differ in the number of neutrons in the nucleus but do not differ in the number of protons. Stable isotopes are not radioactive.

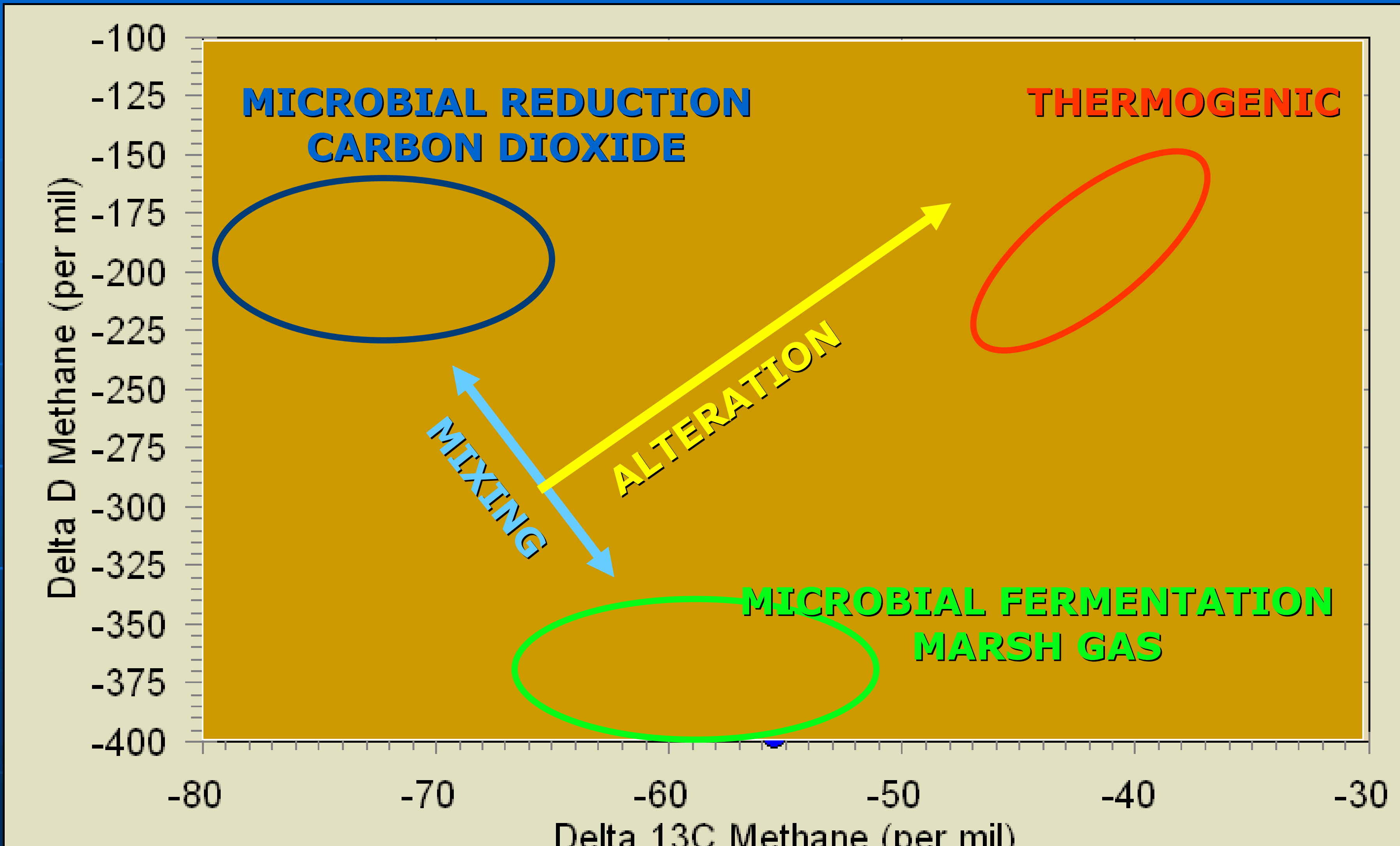


Hydrogen Isotopes

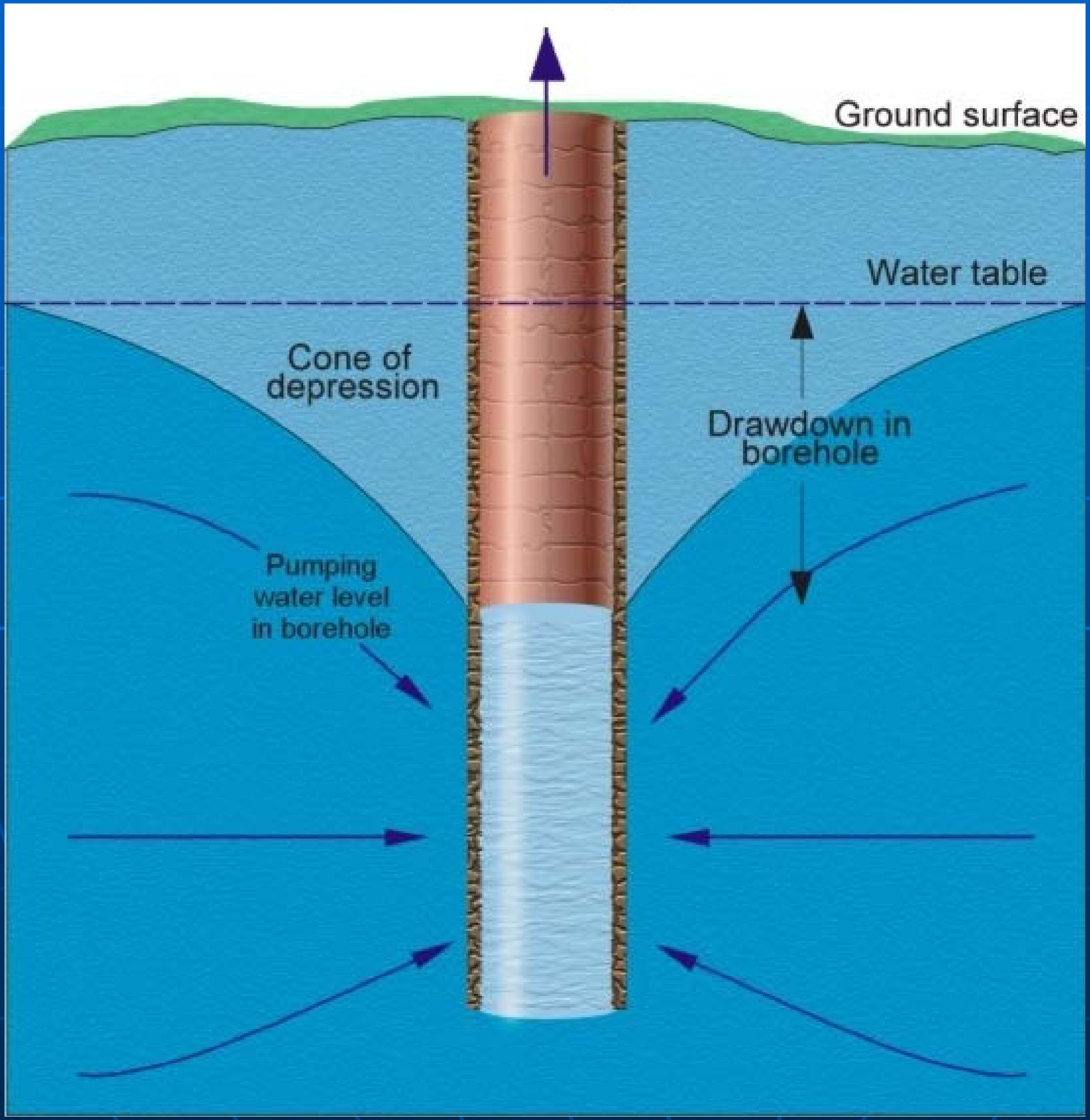
Carbon Isotopes:

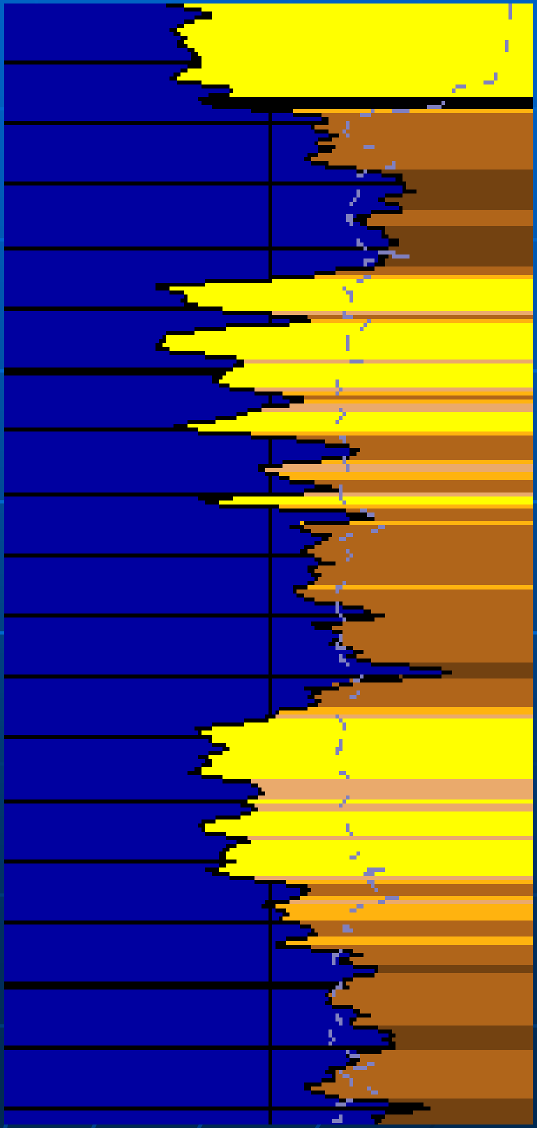
Isotope	Protons	Neutrons	Abundance	Type
^{12}C	6	6	98.98%	Stable
^{13}C	6	7	1.11%	Stable
^{14}C	6	8	trace	Unstable

DISSOLVED METHANE IN GROUNDWATER NEAR SILT IS OF MICROBIAL ORIGIN

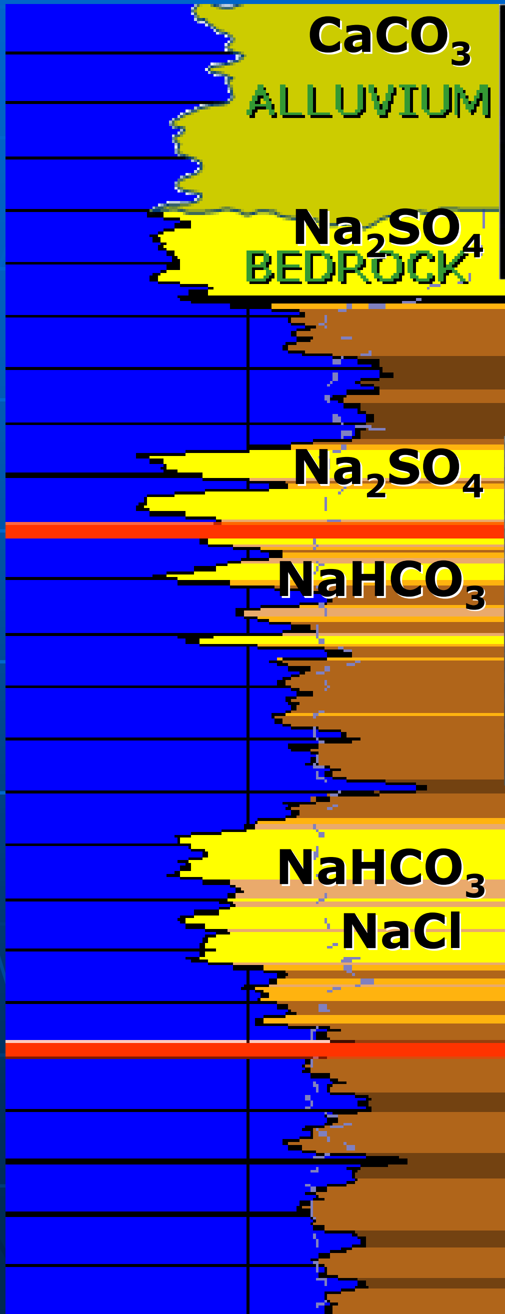


PUMPING AND DRAWDOWN: WHERE DOES THE WATER COME FROM?





PRINCIPAL COMPONENTS OF GROUNDWATER IN THIS AREA



LIME : CALCIUM AND MAGNESIUM BICARBONATE

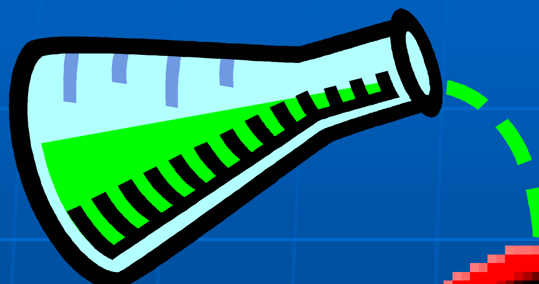
GLAUBER SALT – SODIUM SULFATE

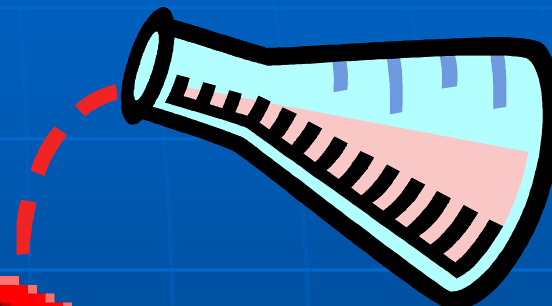
SODIUM BICARBONATE

SODIUM CHLORIDE

COMPOSITION AND CONCENTRATION VARY WITH DEPTH

DISSOLVED SALT AND METHANE CONCENTRATIONS IN WELL WATER PRINCIPALLY CHANGE AS A RESULT OF CHANGING MIXING RATES





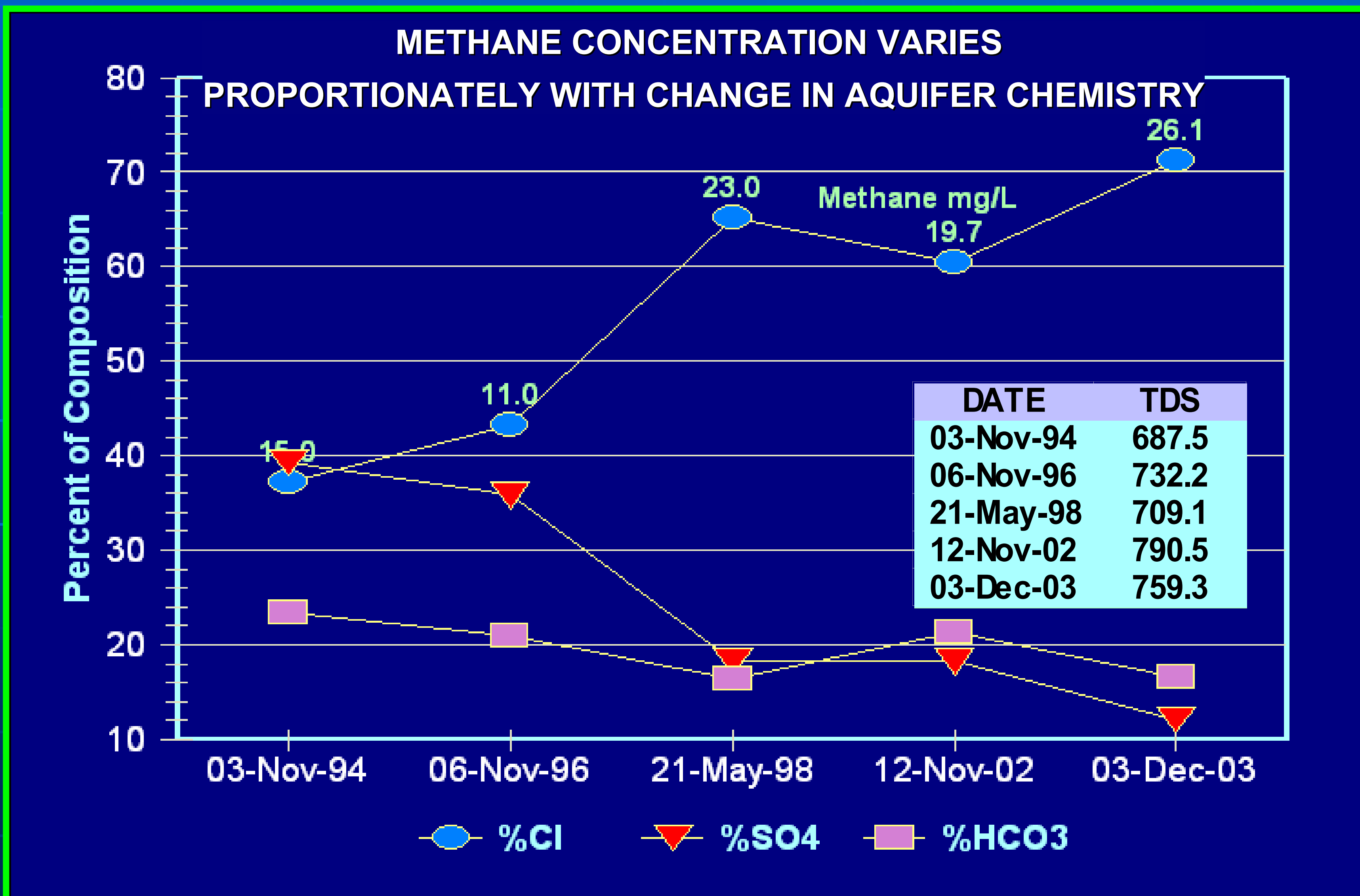
CONCENTRATED

DILUTE

REDUCTION IN YIELD RATES FROM ANY SINGLE AQUIFER WILL CHANGE WATER COMPOSITION

WHAT IF THE SODIUM-CHLORIDE BEARING AQUIFER CARRIES MICROBIAL METHANE?

EXAMPLE OF WELLBORE MIXING AND DILUTION



DATE	TDS
03-Nov-94	687.5
06-Nov-96	732.2
21-May-98	709.1
12-Nov-02	790.5
03-Dec-03	759.3

FACTORS INFLUENCING CHANGES IN AQUIFER YIELD AND WATER QUALITY

- **POPULATION GROWTH**
  - RATE OF RECHARGE VS. RATE OF CONSUMPTION – LOCAL DEPLETION
- **CLIMATIC VARIABILITY**
  - SEASONAL CHANGES
  - LONG TERM CHANGES: E.G. DROUGHT
- **WELL BORE DAMAGE**
  - FOULING: NATURAL BACTERIA

POPULATION GROWTH WILL HAVE LOCAL IMPACT ON SMALLER AQUIFERS

Figure 4-6: Historic and Projected Population, Division 5

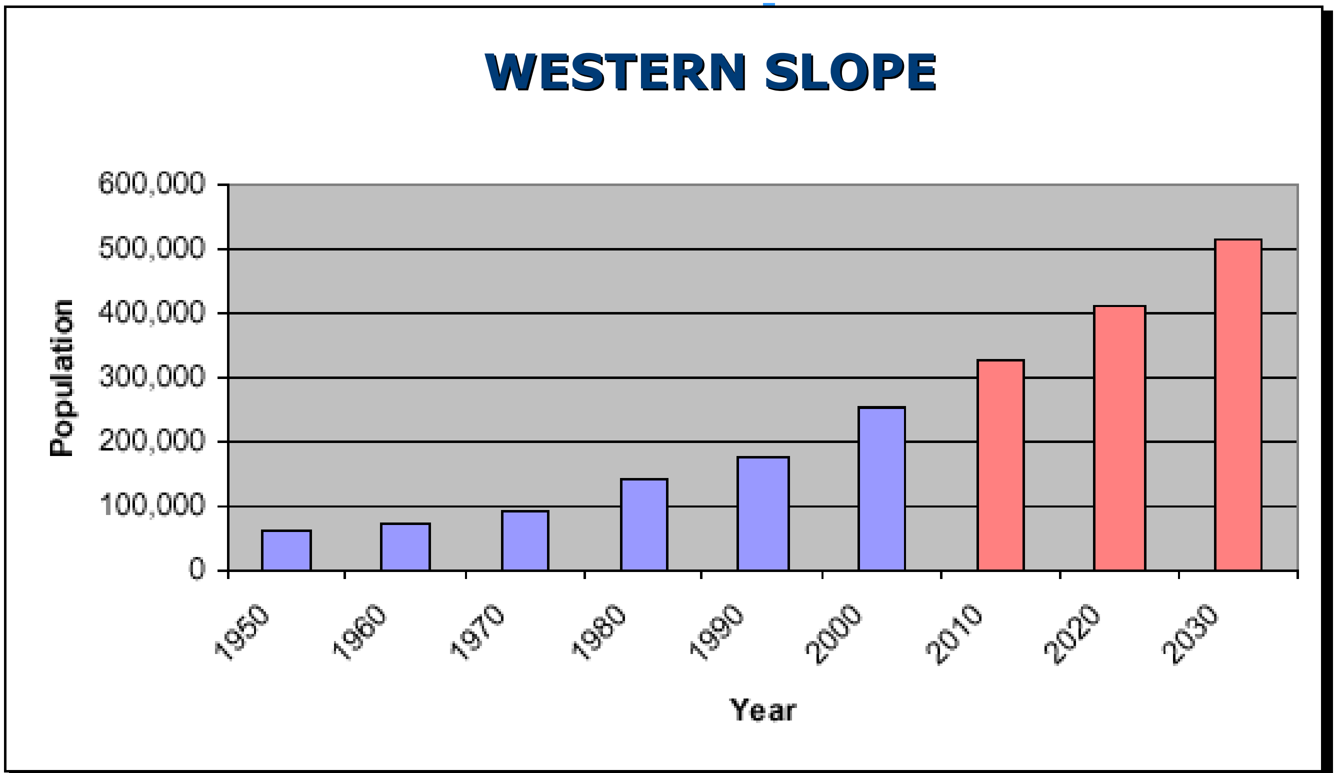


Table 4-7: Projected Population Change in Division 5

Division 5	2000	2010	2030	Annual Growth Rate '00-'10	Annual Growth Rate '10-'30
Grand County	12,900	16,800	29,700	2.7%	2.9%
Summit County	25,700	32,500	50,600	2.4%	2.2%
Eagle County	43,400	57,100	90,000	2.8%	2.3%
Pitkin County	15,900	18,700	27,600	1.6%	2.0%
Garfield County	44,300	58,700	99,000	2.9%	2.6%
Mesa County (Grand Junction)	117,700	144,100	220,400	2.0%	2.1%
TOTAL	**259,800**	**327,700**	**517,300**	**2.3%**	**2.3%**

SEASONAL FLOW INFLUENCES THE RATE OF FRESH WATER RECHARGE TO SHALLOW AQUIFERS

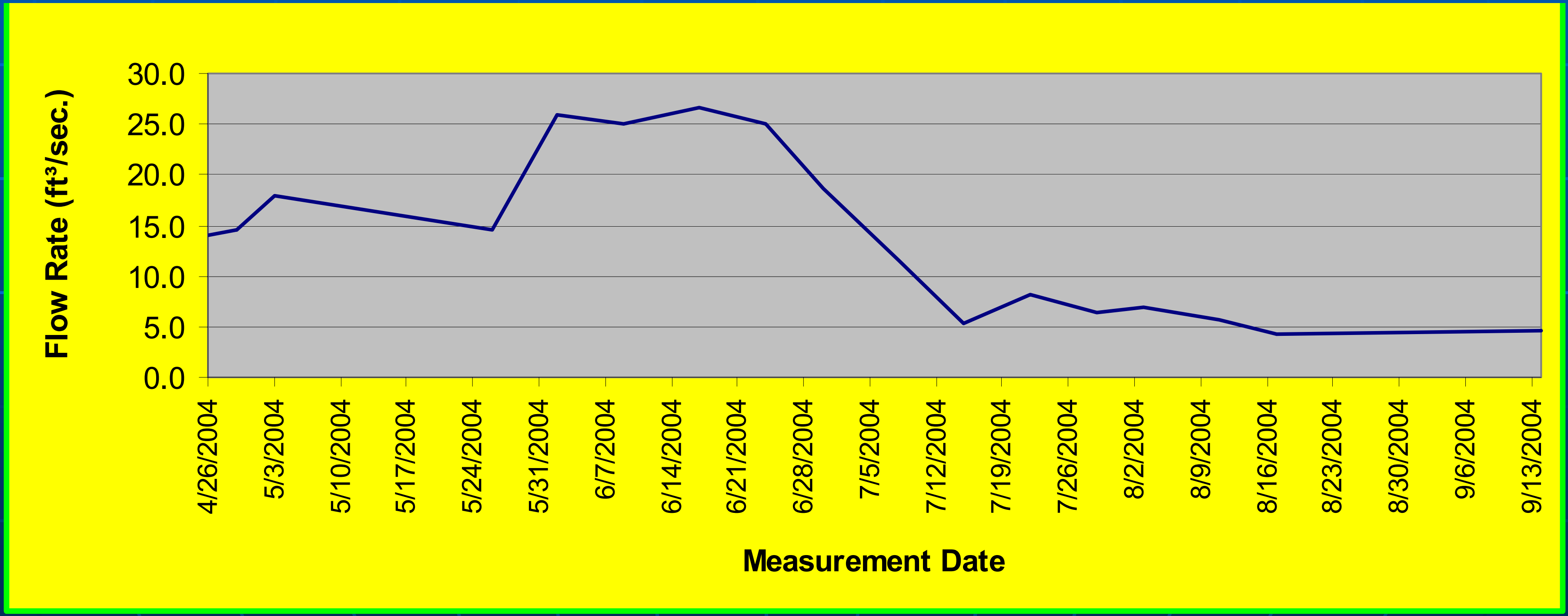
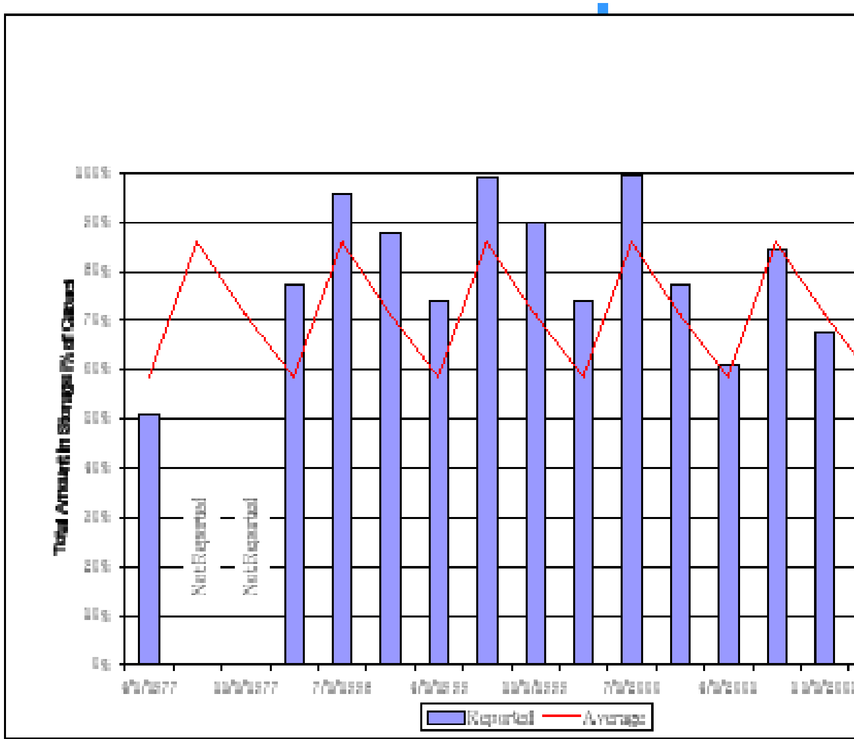
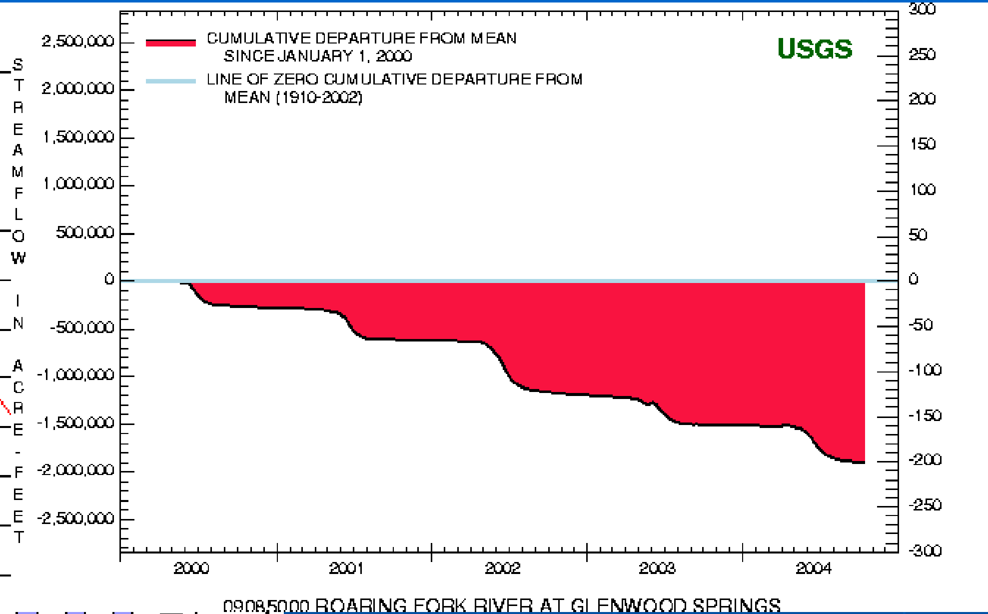
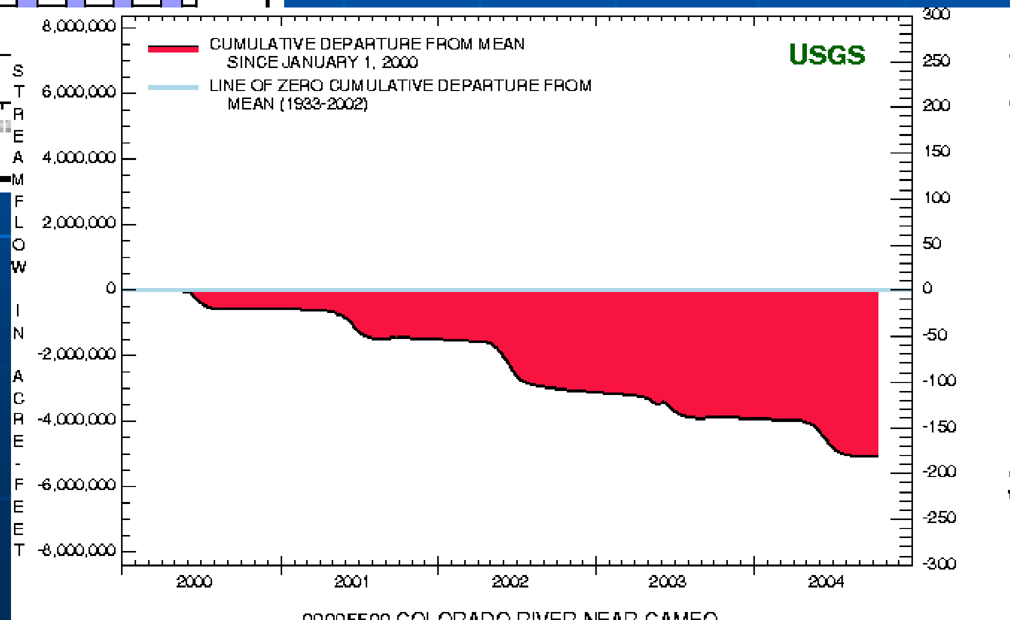


Figure 6-5: Division 5 Carryover Storage







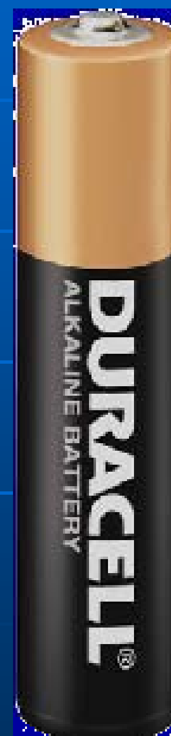
LONG TERM DROUGHT IS HAVING A SIGNIFICANT IMPACT ON RECHARGE

http://cwcb.state.co.us/owc/Drought_Water/pdf/Chapter%206.pdf

CHEMICAL REACTIONS IN AQUIFERS ARE MEDIATED BY NATURAL BACTERIA

OXIC

+



-

ANOXIC

REDUCTION REACTIONS

- Loss of dissolved oxygen
- Loss of Nitrate
  - ($NO_3^- \rightarrow NH_4^+$)
- Manganese Reduction
  - ($Mn^{+4} \rightarrow Mn^{+3}$)
- Iron Reduction
  - ($Fe^{+3} \rightarrow Fe^{+2}$)
- Sulfate Reduction
  - ($SO_4^{-2} \rightarrow HS^- \rightarrow S^o$)
- CO_2 Reduction
  - ($CO_2 \rightarrow CH_4$)
- Nitrogen Reduction
  - ($N_2 \rightarrow NH_4^+$)

OXIDATION REACTIONS

- Oxygen formation
- Denitrification
  - ($N_2 \rightarrow NO_3^-$)
- Manganese Oxidation
  - ($Mn^{+3} \rightarrow Mn^{+2}$)
- Ammonia Oxidation
  - ($NH_4^+ \rightarrow NO_3^-$)
- Iron Oxidation
  - ($Fe^{+2} \rightarrow Fe^{+3}$)
- Sulfate Oxidation
  - ($S^o \rightarrow HS^- \rightarrow SO_4^{-2}$)
- Oxidation of Organics
  - ($CH_4 \rightarrow CO_2$)

BACTERIA CAN SEVERLY IMPACT THE AESTHETIC QUALITY OF WATER

80% OF WELL CLOGGING EVENTS MEDIATED BY BACTERIA

TURBID SLIME




STAGNANT WATER PROMOTES THE FOLLOWING NATURAL REACTIONS THAT DETERIORATE WATER QUALITY

SRBs

Sulfuric Acid
(corrosion)

AIR

SO_4 + Organics -> Sulfide + CO_2

\+

Hardness

Mineral Scale
PRECIPITATION
Increasing SAR

IRBs

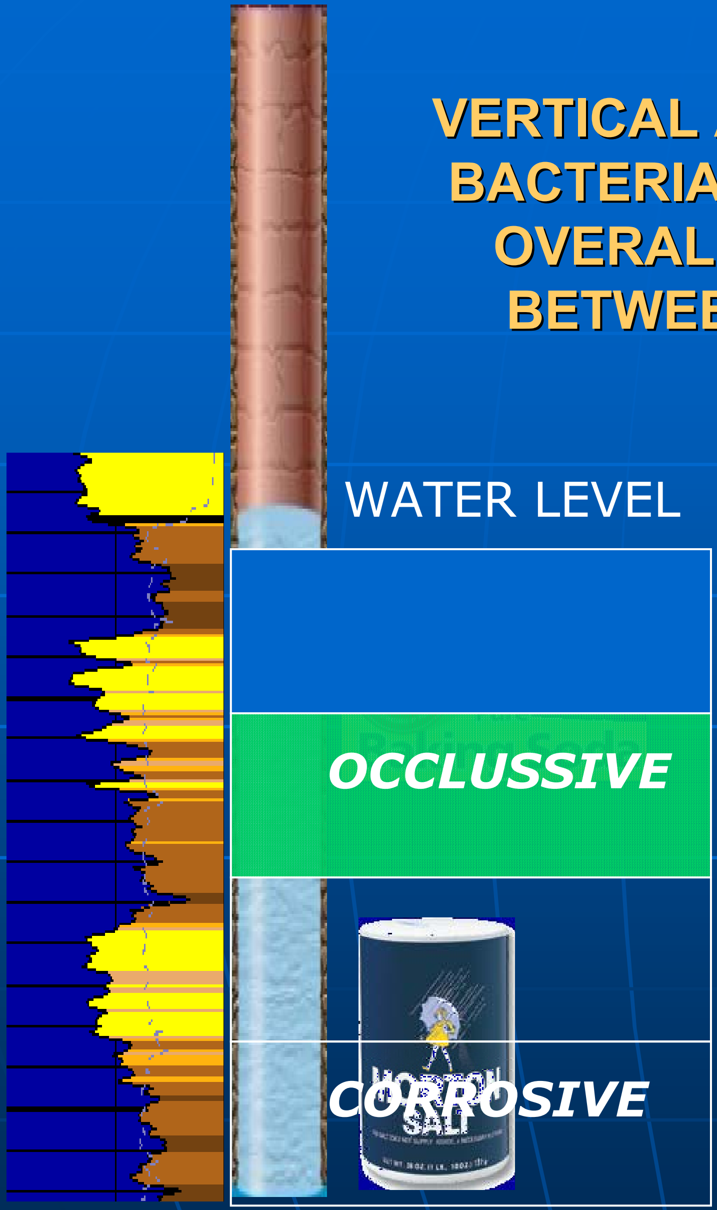
Dissolved
Iron

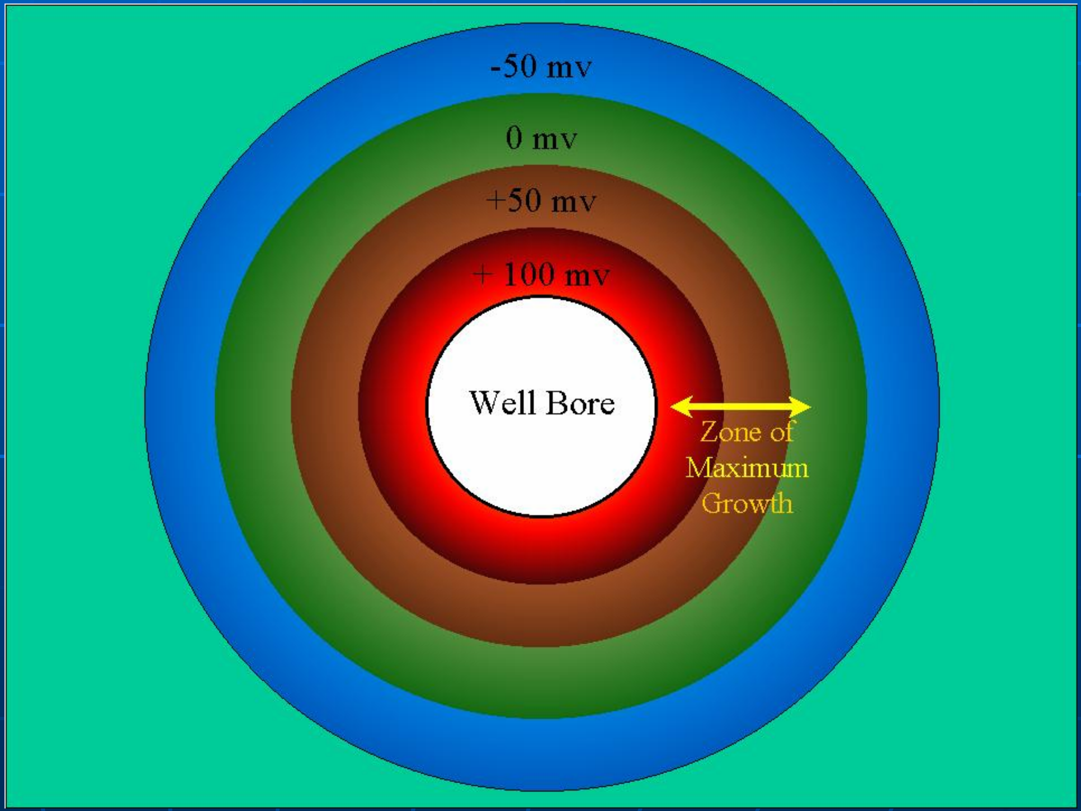
Iron Sulfide
Gray Color
Poor Taste

AIR

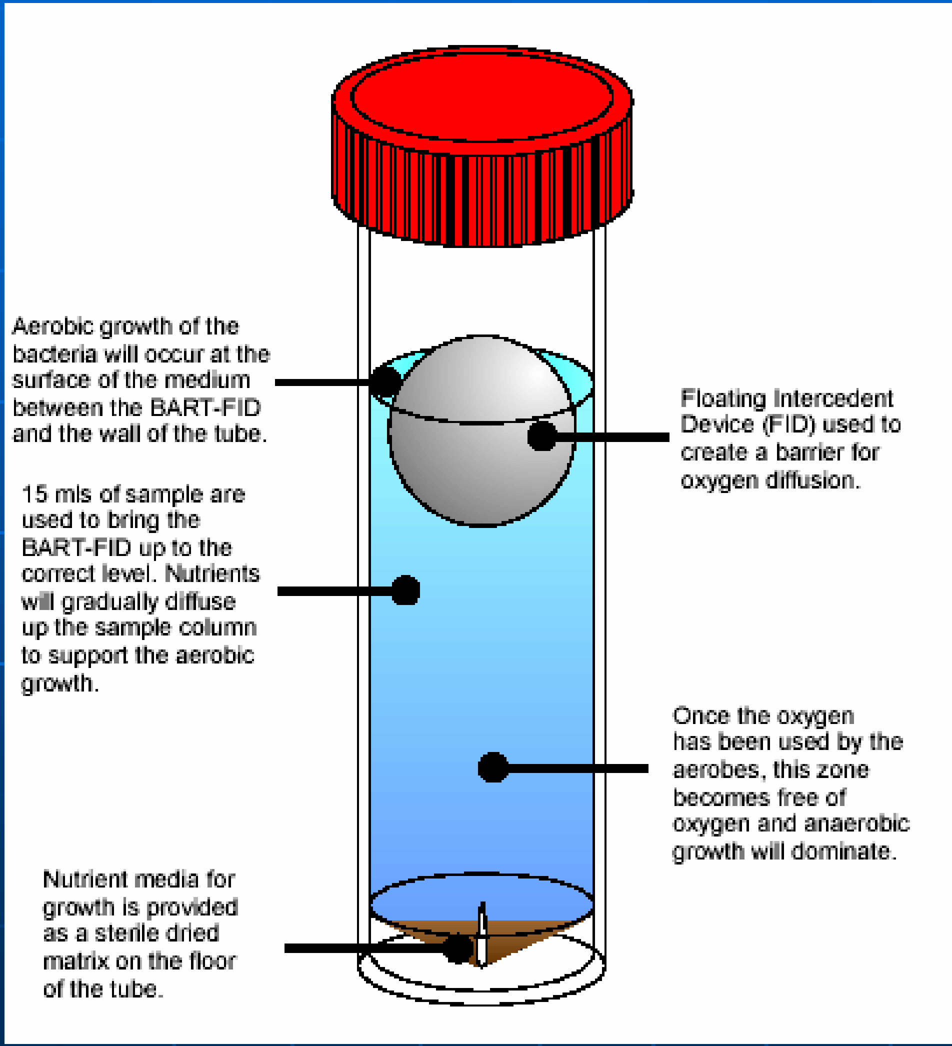
Rust Stain
Poor Taste

VERTICAL AND HORIZONTAL DISTRIBUTION OF BACTERIAL ZONES CAN GRADUALLY AFFECT OVERALL WELL YIELD AND MIXING RATES BETWEEN AQUIFERS TAPPED BY A WELL





BIOLOGIC ACTIVITY REACTION TESTS (BART™) TO CHECK FOR PRESENCE OF BACTERIA



SRB – SULFATE REDUCING BACTERIA
IRB – IRON RELATED BACTERIA
HAB – AEROBIC HETEROTROPHIC
SLYM –SLIME FORMING BACTERIA

From: Biological Activity Reaction Test BART™User Manual
©2003 Edition, Droycon Bioconcepts Inc.Regina, Saskatchewan, Canada

RELATIONSHIP BETWEEN TIME LAG (IN DAYS TO FIRST REACTION) AND BACTERIAL COLONY-FORMING UNITS

TIME LAG (days)	IRB CFU	SRB CFU	HAB CFU	SLYM CFU
0.5	3,981,072	3,981,072	6,309,573	6,309,573
1.0	1,000,000	1,000,000	3,981,072	3,981,072
1.5	630,957	630,957	630,957	630,957
2.0	100,000	100,000	398,107	398,107
3.0	10,000	39,811	1,000	39,811
4.0	3,981	10,000	100	1,000
5.0	1,000	3,981	10	398
6.0	100	1,000	10	100
7.0	100	100	10	10
8.0	100	100	10	10

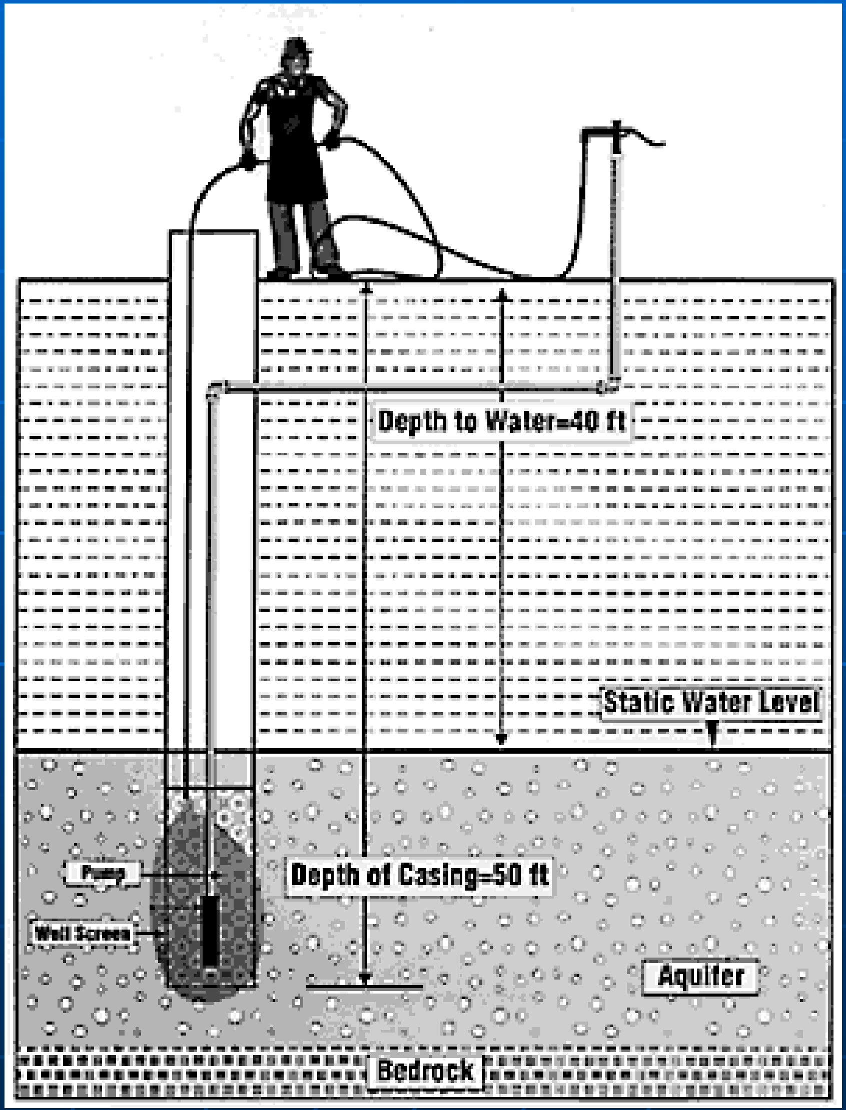
APPROACHES TO ALLEVIATING BACTERIAL FOULING

- MECHANICAL AGITATION OF THE WELL BORE
  - SURGING
  - WATER JETTING
  - SCRUBBING
  - AIR SPARGING
- FLUSHING TO REMOVE SUSPENDED OR SOLUBLE DEBRIS THAT HAVE BEEN PHYSICALLY REMOVED BY MECHANICAL AGITATION.
- ACIDIFICATION TO SOLUBLIZE MINERALS AS WELL AS THE POLYSACCHARIDE PORTION OF BIOLOGICAL SLIMES.
  - THE THREE MOST COMMONLY USED ACIDS
    - HYDROCHLORIC (HCl)
    - SULFAMIC (H_3NO_3S)
    - HYDROXYACETIC ($C_2H_4O_3$).
- THE USE OF BACTERICIDES TO SUPPRESS BACTERIAL POPULATIONS.
  - SHOCK DISINFECTION

CONSULT YOUR WATER WELL PROFESSIONAL

WHEN TO SHOCK DISINFECT YOUR WATER WELL

- WHEN LAB RESULTS INDICATE PRESENCE OF BACTERIA
- WHEN COLOR AND ODOR INDICATE THE PRESENCE OF BACTERIA
- UPON COMPLETION OF A NEW WELL OR AFTER PUMP REPLACEMENT OR REPAIR
- WHEN THE DISTRIBUTION SYSTEM IS OPENED FOR REPAIRS OR MAINTENANCE
- FOLLOWING CONTAMINATION BY FLOOD WATER



http://wilkes1.wilkes.edu/~eqc/shock1.htm

CONCLUSIONS

- CHANGES IN WATER YIELD AND QUALITY ARE NATURAL
- BE AWARE OF CHANGES
- MAKE SURE YOU KNOW HOW YOUR WATER WELL IS CONSTRUCTED
- TAKE THE TIME TO LEARN HOW TO INTERPRET YOUR WATER WELL LABORATORY DATA REPORTS
- EVALUATE RESULTS BASED ON WATER WELL CONSTRUCTION AND SEASONAL CHANGES
- ACT ON RESULTS…NEGLECT WILL RESULT IN DAMAGE THAT IS DIFFICULT TO REMEDIATE
- REGULARLY INSPECT AND TREAT YOUR WATER WELL TO OPTIMIZE YIELD AND WATER QUALITY
- WHEN IN DOUBT, CONSULT A PROFESSIONAL

QUESTIONS AND ANSWERS

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