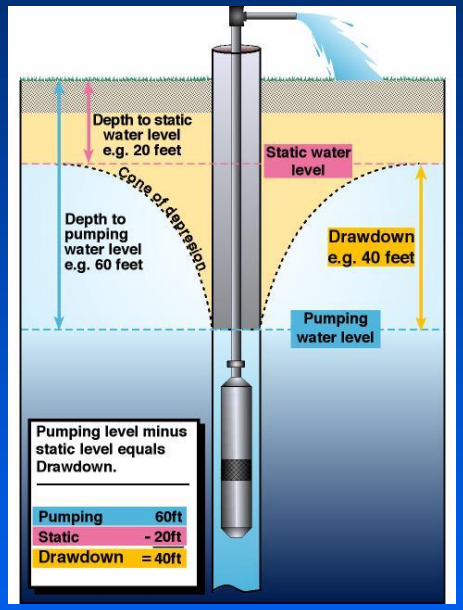
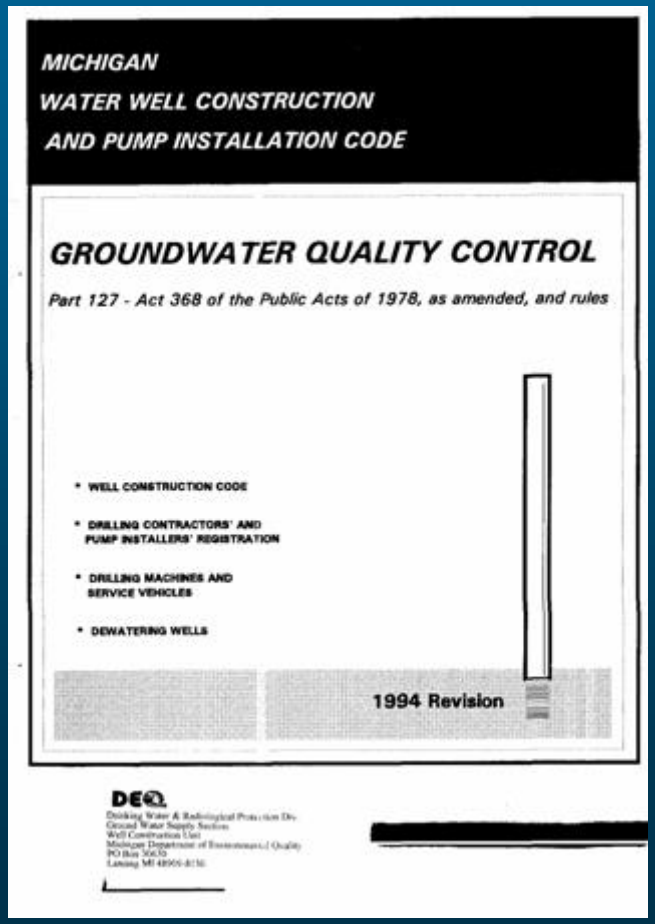
WATER WELL CONSTRUCTION



Statute: Part 127 – Water Supply and Sewer Systems Act 368, PA 1978, as amended (Public Health Code) (MCLA 333.12701 – 12715)



R 325.1601 – 325.1781

- *Part 1 – Well Construction Code*
- *Part 2 - Drilling Contractors' & Pump Installers' Registration*
- *Part 3 – Drilling Machines & Service Vehicles*
- *Part 4 - Dewatering Wells*

FIRST BECAME EFFECTIVE FEB. 14, 1967
LAST REVISION – EFFECTIVE APRIL 21, 1994

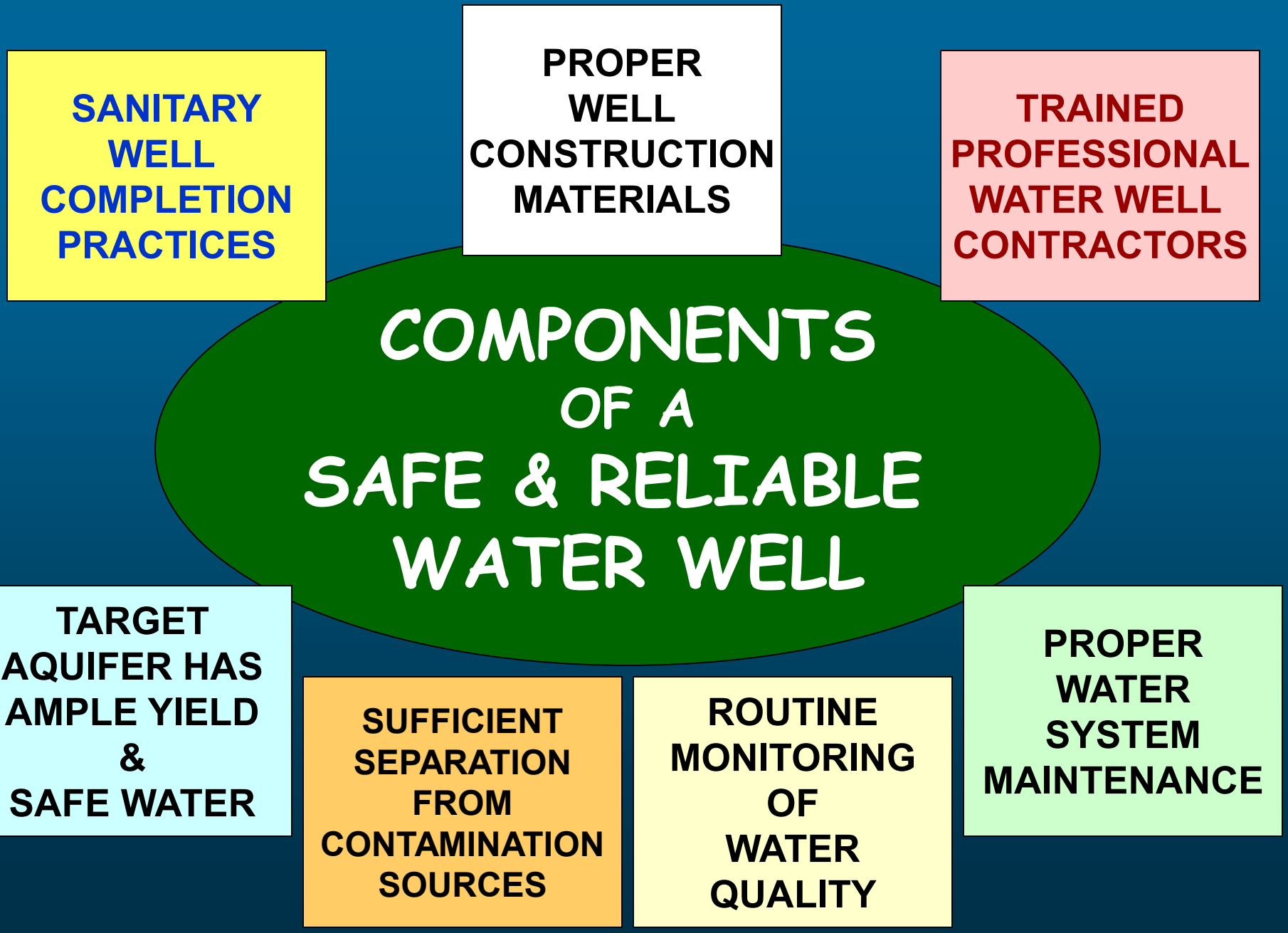
For public water supply wells - Apply Part 8, Act 399, PA 1976 in addition to Part 127, Public Health Code

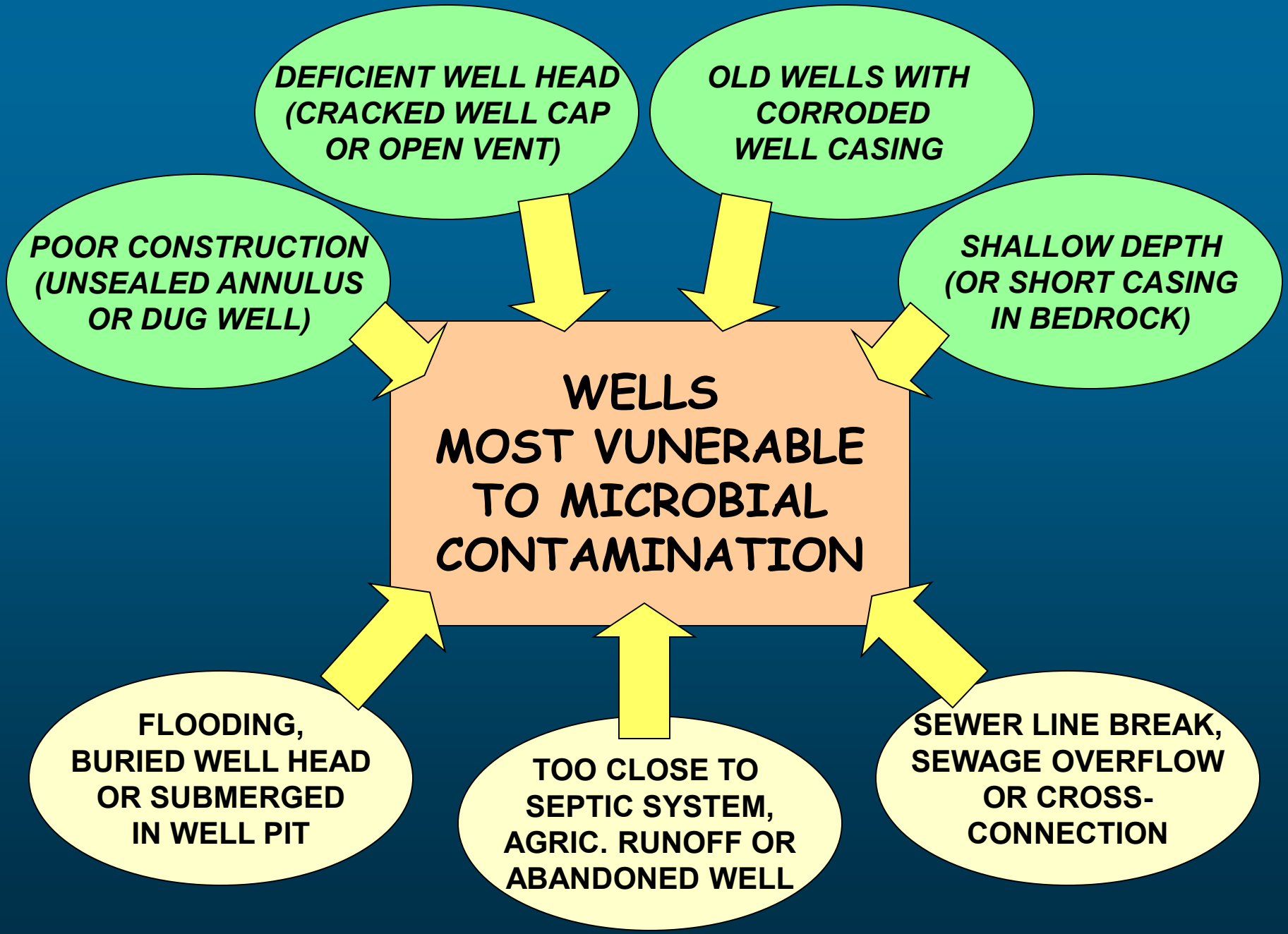
U. S. Commerce, Bureau of Census

1990 Detailed Housing Characteristics

1.12 million household wells in Michigan

HIGHEST IN NATION!

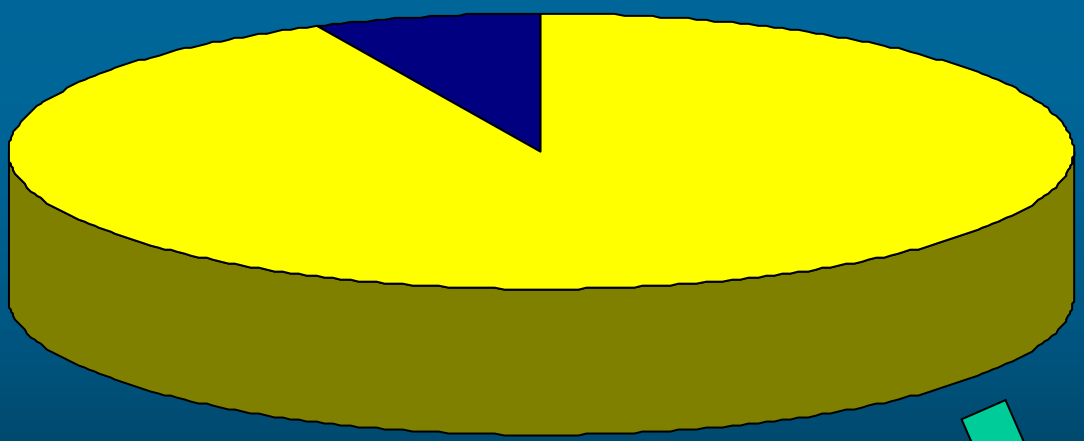

SANITARY WELL COMPLETION PRACTICES
PROPER WELL CONSTRUCTION MATERIALS
TRAINED PROFESSIONAL WATER WELL CONTRACTORS
COMPONENTS OF A SAFE & RELIABLE WATER WELL
TARGET AQUIFER HAS AMPLE YIELD & SAFE WATER
SUFFICIENT SEPARATION FROM CONTAMINATION SOURCES
ROUTINE MONITORING OF WATER QUALITY
PROPER WATER SYSTEM MAINTENANCE


DEFICIENT WELL HEAD (CRACKED WELL CAP OR OPEN VENT)
OLD WELLS WITH CORRODED WELL CASING
POOR CONSTRUCTION (UNSEALED ANNULUS OR DUG WELL)
SHALLOW DEPTH (OR SHORT CASING IN BEDROCK)
WELLS MOST VUNERABLE TO MICROBIAL CONTAMINATION
FLOODING, BURIED WELL HEAD OR SUBMERGED IN WELL PIT
TOO CLOSE TO SEPTIC SYSTEM, AGRIC. RUNOFF OR ABANDONED WELL
SEWER LINE BREAK, SEWAGE OVERFLOW OR CROSS-CONNECTION

WATER WELL USE

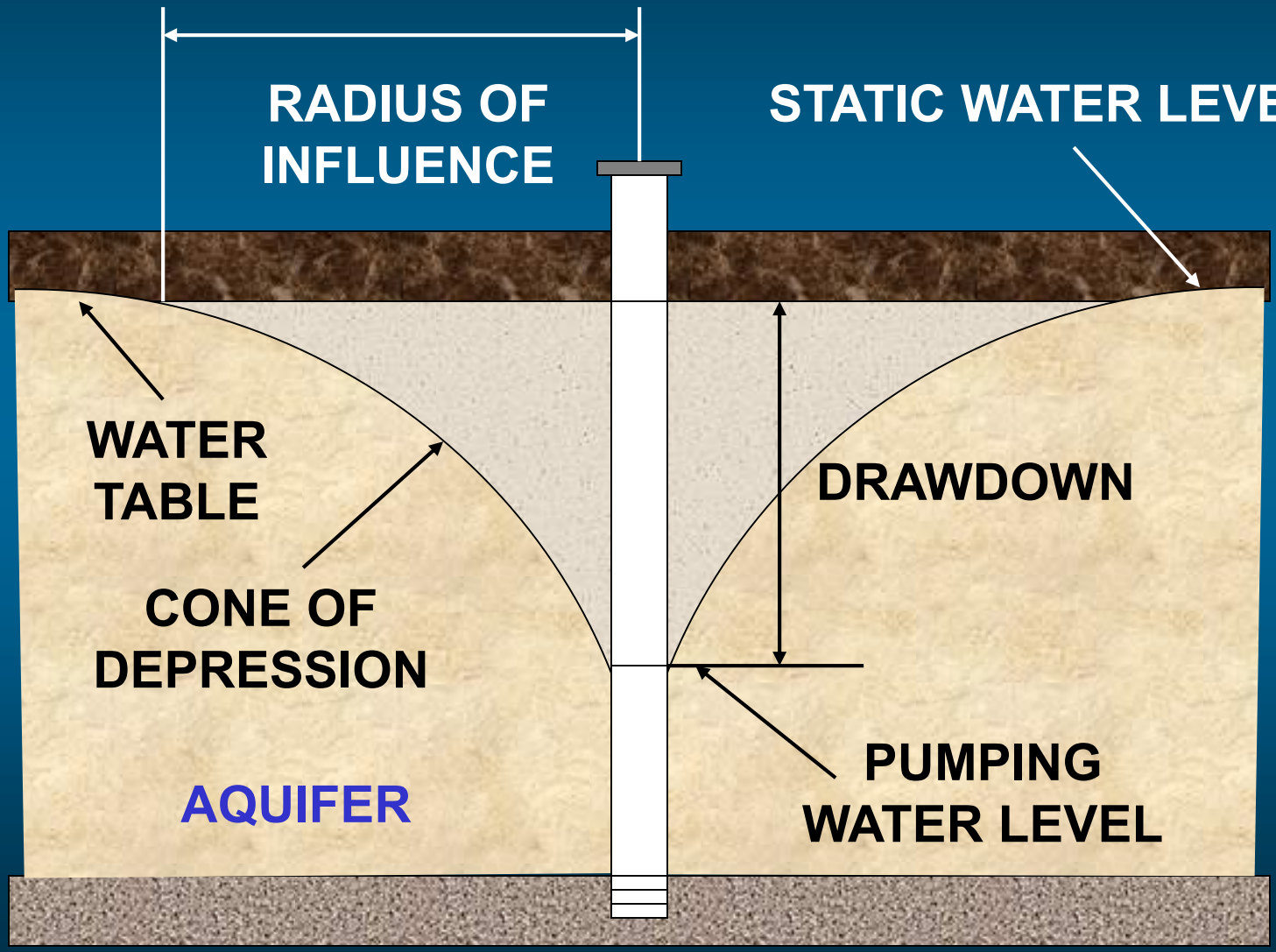
OTHER 2%

PUBLIC SUPPLY
AGR. IRRIGATION
INDUSTRIAL
TEST WELL
OTHER

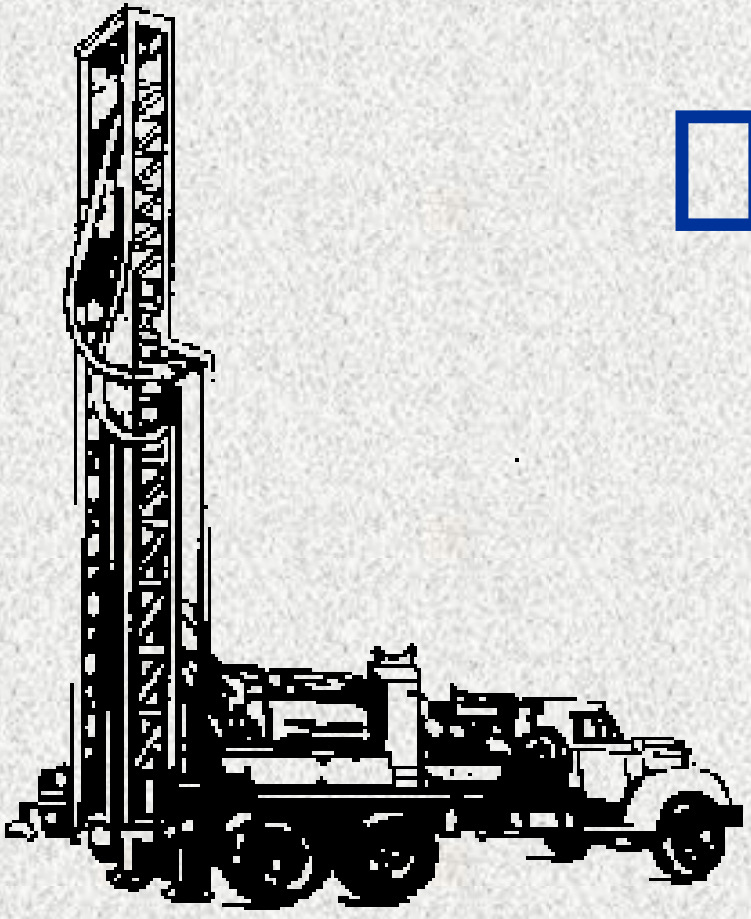


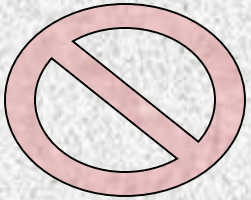
HOUSEHOLD 98%

COMMON WATER WELL TERMS



Types of Water Wells



- DRILLED
- DRIVEN
- DUG 

WATER WELL DESIGN

- Provide well that meets needs of owner
- Obtain highest yield with minimal drawdown (consistent w/ aquifer capabilities)
- Provide suitable quality water (potable and turbidity-free for drinking water wells)
- Provide long service life (25+ years)

NEW: Minimize impacts on neighboring wells & aquatic environments

DRILLED WELLS

- Terminated in glacial drift (sand, gravel) or bedrock
- Constructed with rotary, cable tool, jetting, hollow rod or auger drilling methods
- 2 in. or larger casing (Domestic wells: 4 – 6 inch diameter)

DRILLED WELLS

- Casing material: Steel or PVC plastic
- Installed by well drilling contractors
- Much more common than driven or dug wells
- Most are >50 ft. deep (avg. 125 ft.)
- *MOST SANITARY WELL TYPE*

WATER WELL DRILLING METHODS
IN MICHIGAN

MOST COMMON:

ROTARY
(Mud & Air)

84%

LESS COMMON:

CABLE TOOL
10%

AUGER
2.5%

JETTING
1%

HOLLOW ROD
0.5%

OTHER
2%

EMERGING TECHNOLOGY

DUAL TUBE ROTARY

HORIZONTAL

SONIC


Rotary


Cable Tool

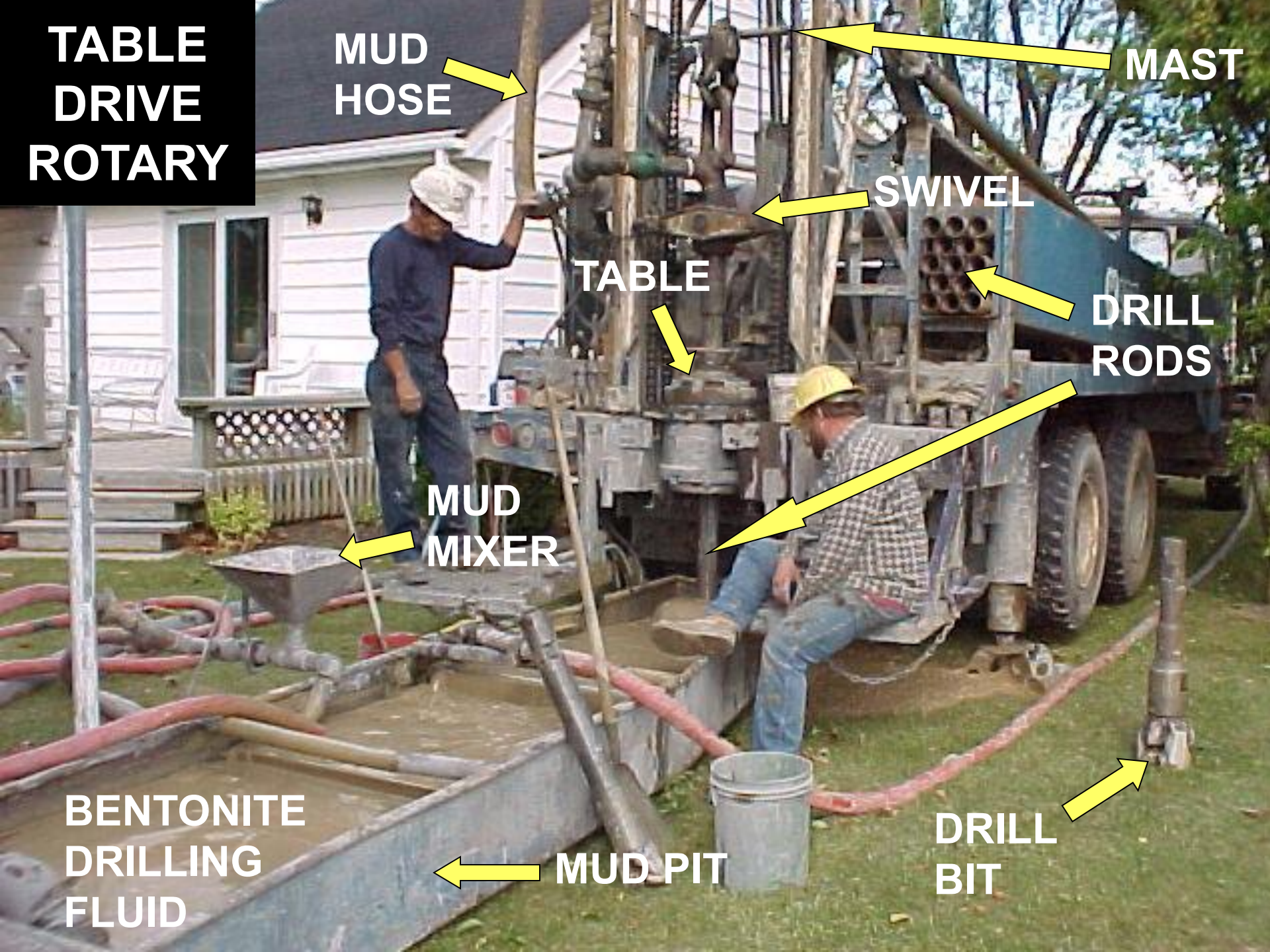
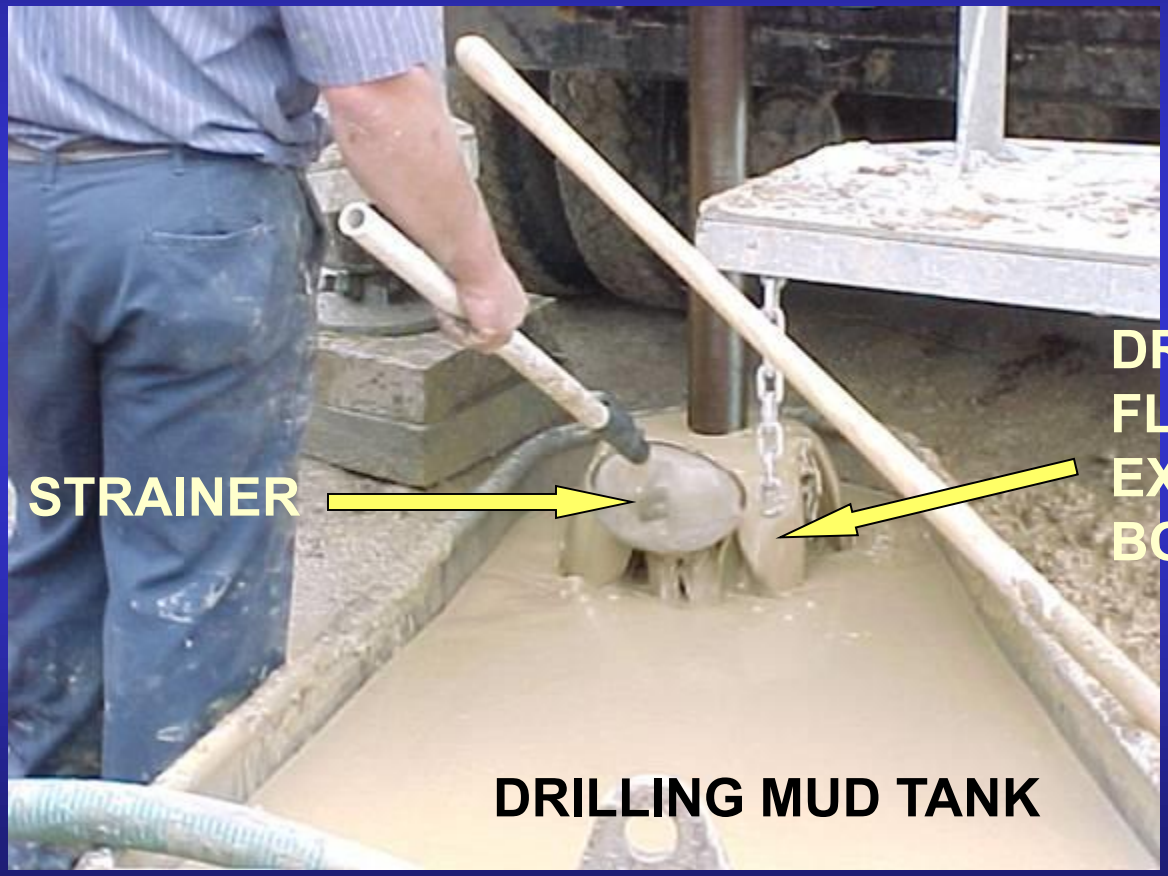


TABLE DRIVE ROTARY
MUD HOSE
MAST
SWIVEL
TABLE
DRILL RODS
MUD MIXER
BENTONITE DRILLING FLUID
MUD PIT
DRILL BIT

TOP HEAD DRIVE ROTARY

DRILLING RIG OPERATOR CHECKING DRILL CUTTINGS

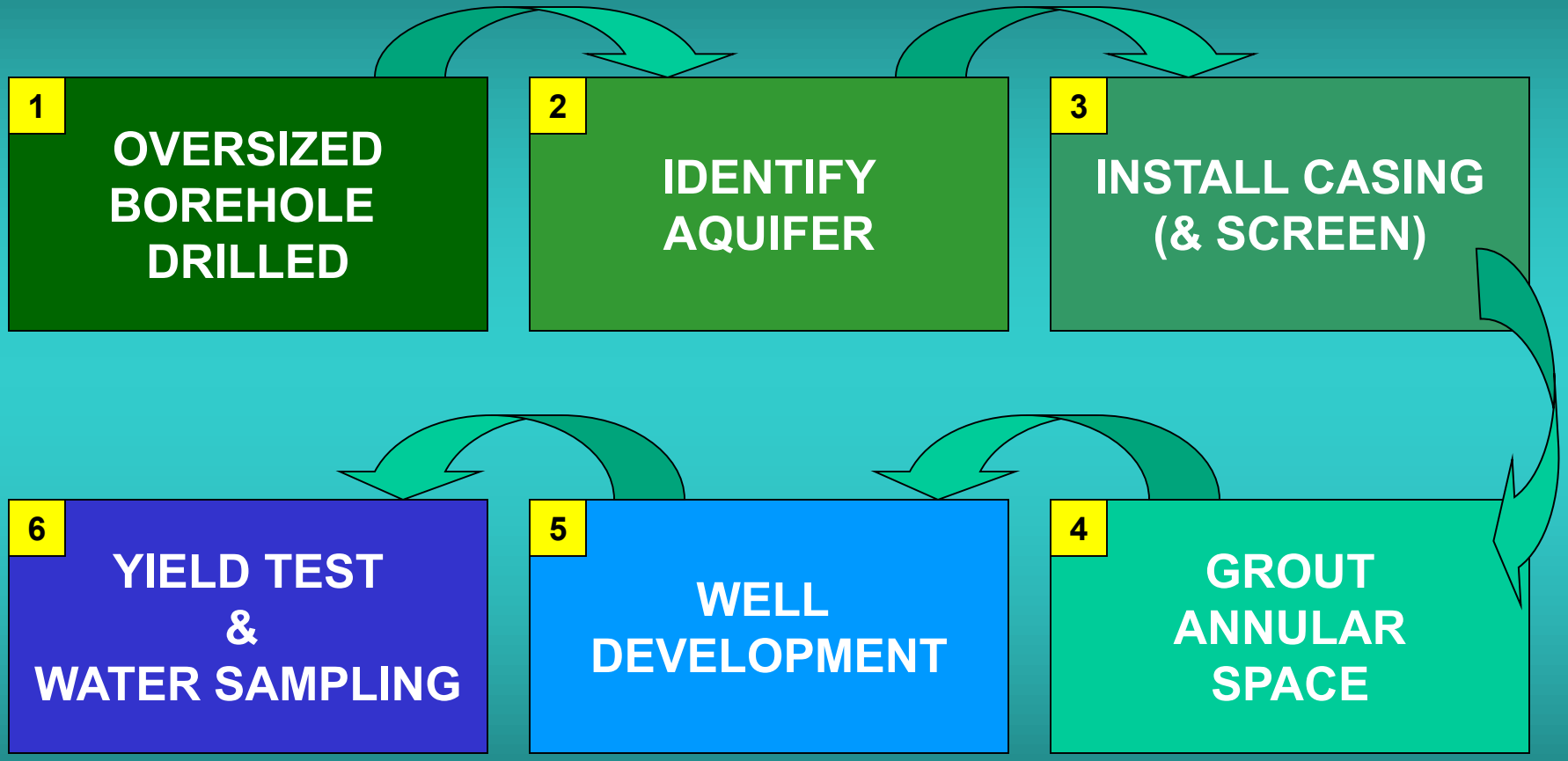


DRILLER COMPLETING THE WATER WELL RECORD

WATER WELL & PUMP RECORD DESCRIBES:

WELL DEPTH
CASING LENGTH
GEOLOGIC MATERIALS PENETRATED
STATIC WATER LEVEL
PUMPING WATER LEVEL
PUMPING RATE
GROUTING MATERIALS
WELL LOCATION
PUMPING EQUIPMENT
DRILLERS NAME
DRILLING RIG OPERATOR

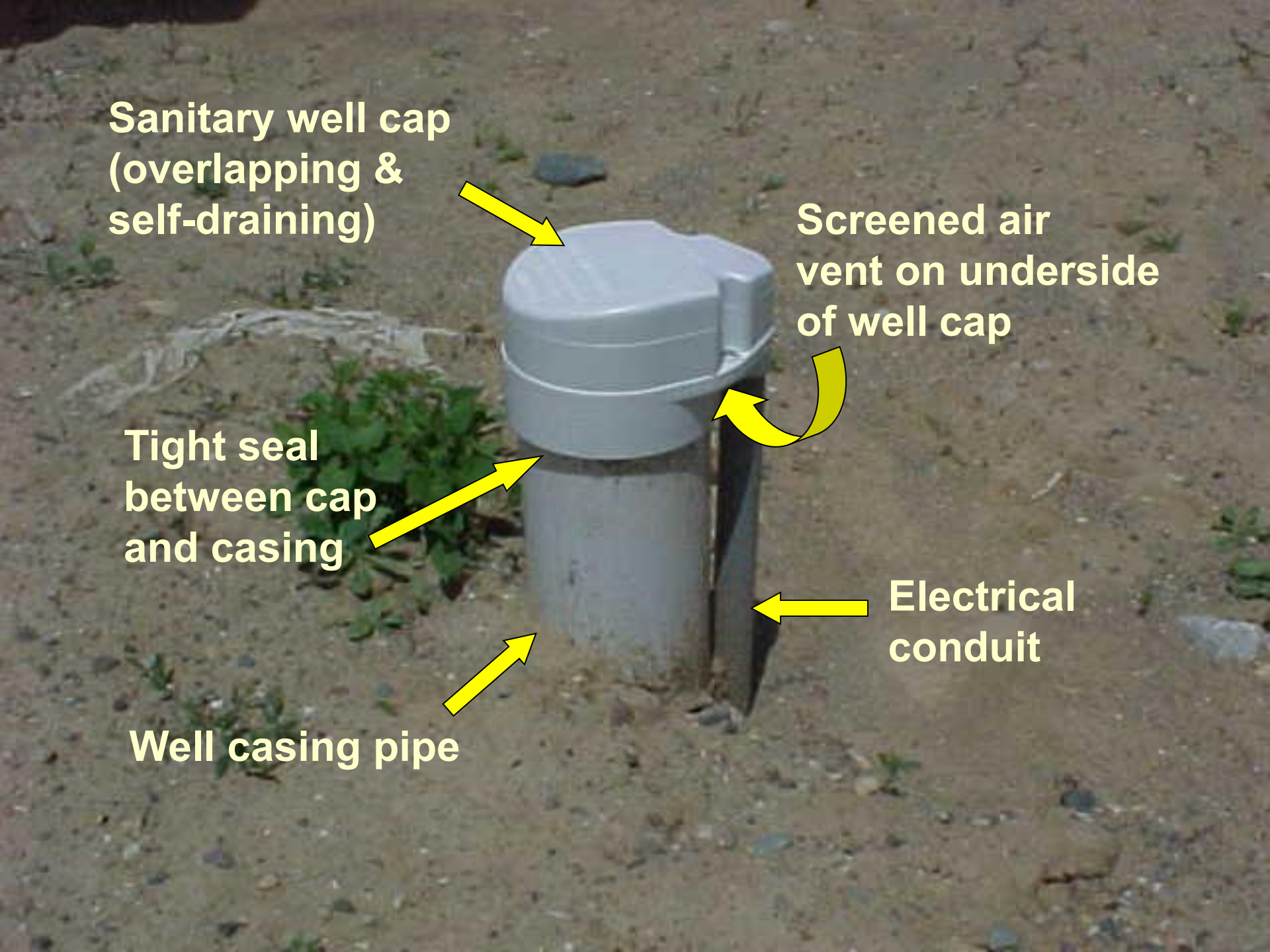
TYPICAL ROTARY WELL CONSTRUCTION SEQUENCE



Bentonite Drilling Fluid
- *Functions* -

- REMOVAL OF DRILL CUTTINGS FROM BOREHOLE
- STABILIZE THE BOREHOLE
- COOL AND LUBRICATE DRILL BIT
- CONTROL FLUID LOSS TO GEOLOGIC FORMATIONS
- DROP DRILL CUTTINGS INTO MUD PIT
- FACILITATE COLLECTION OF GEOLOGIC DATA
- SUSPEND CUTTINGS WHEN DRILLING FLUID CIRCULATION STOPS

Temporary well cap - installed between well drilling and pump hook-up

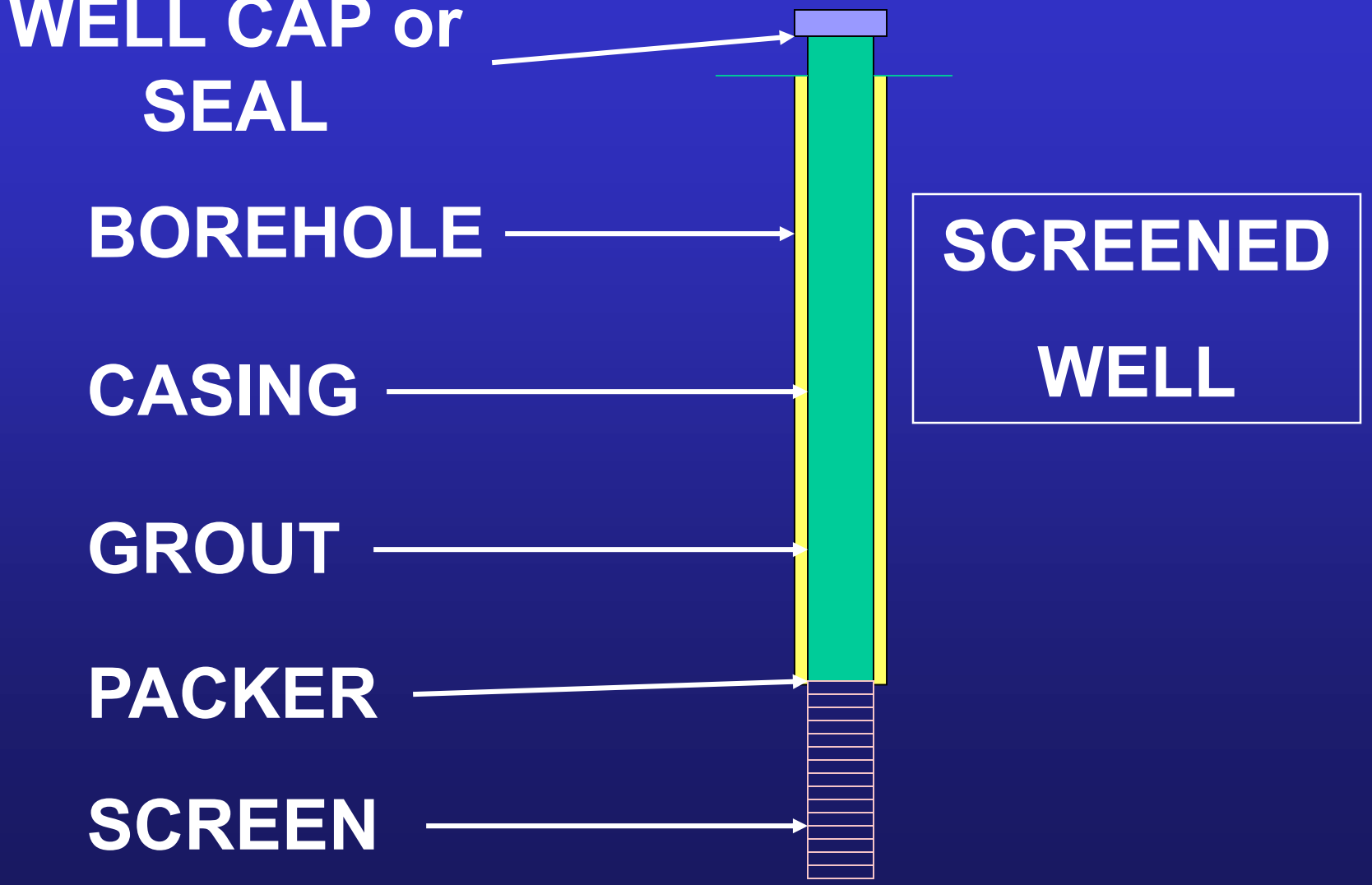

Sanitary well cap (overlapping & self-draining)
Screened air vent on underside of well cap
Tight seal between cap and casing
Electrical conduit
Well casing pipe

This drilled well has an older style well cap that does not seal tightly to the well casing.

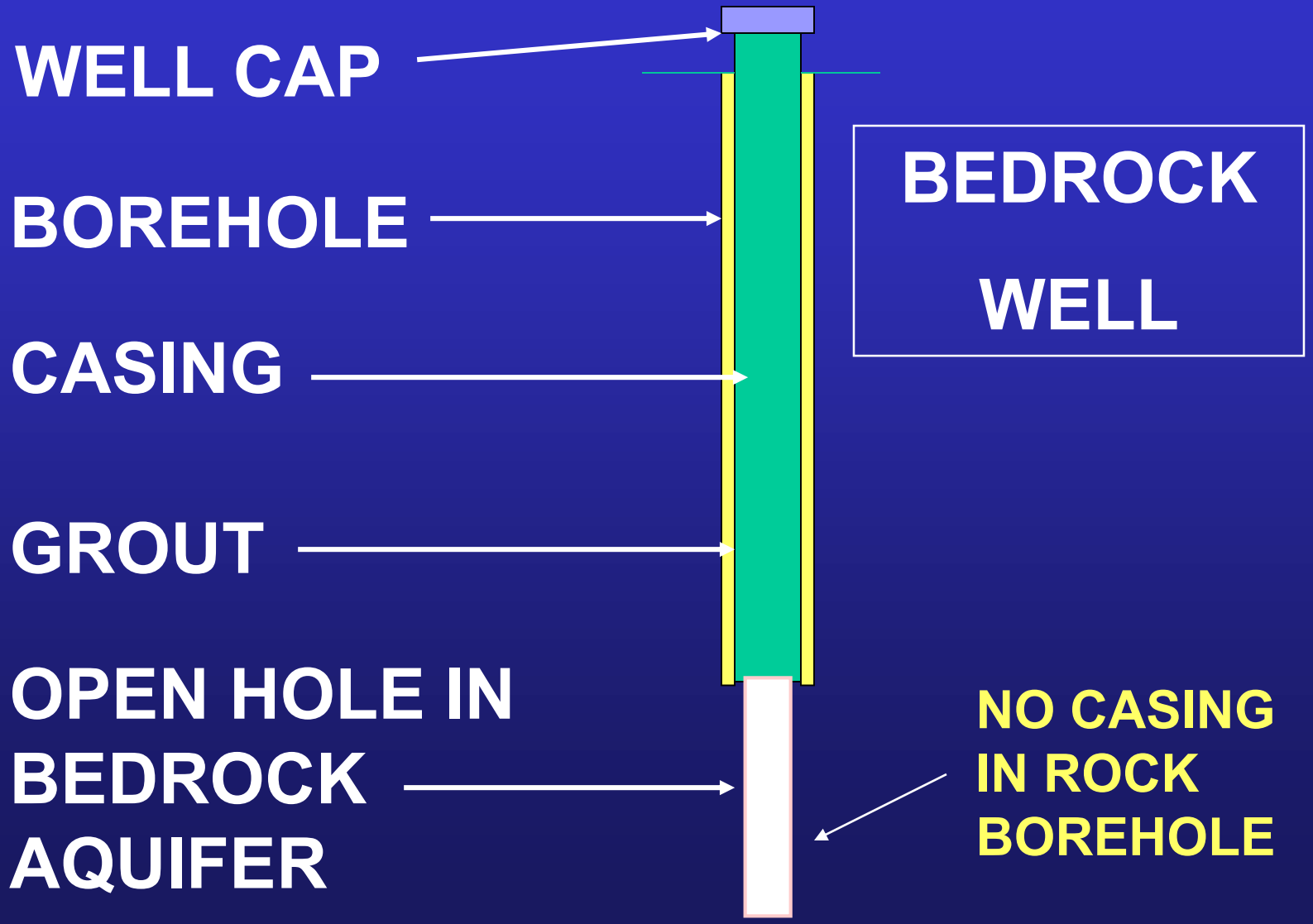
Insects and small animals can enter the well and contaminate the drinking water.

Caps of this design are not acceptable and should be replaced.

DRILLED WELL COMPONENTS



DRILLED WELL COMPONENTS



BOREHOLE

Vertical circular boring to reach aquifer (water bearing geologic material)

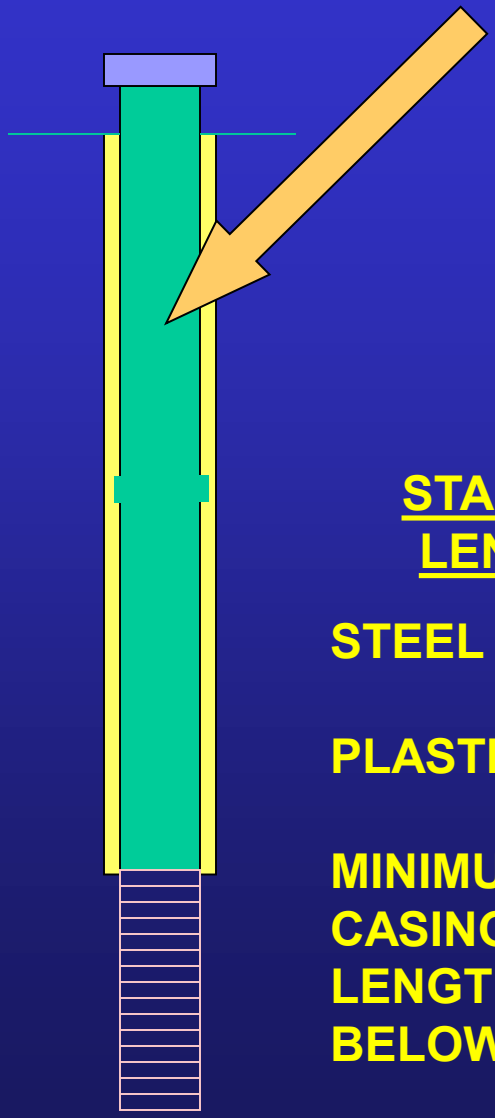
MINIMUM 2 IN. LARGER THAN CASING IF GROUTING THRU CASING

MINIMUM 2 7/8 IN. LARGER THAN CASING IF GROUTING WITH GROUT PIPE OUTSIDE CASING

CASING

Steel or plastic pipe installed to keep borehole wall from collapsing

Houses submersible pump or turbine bowls & drop pipe



STANDARD LENGTHS

STEEL	21 FT.
PLASTIC	20 FT.
MINIMUM CASING LENGTH BELOW GRADE	25 FT.

WELL CAP or SEAL

Mechanical device to prevent contaminants (including insects) from entering well casing

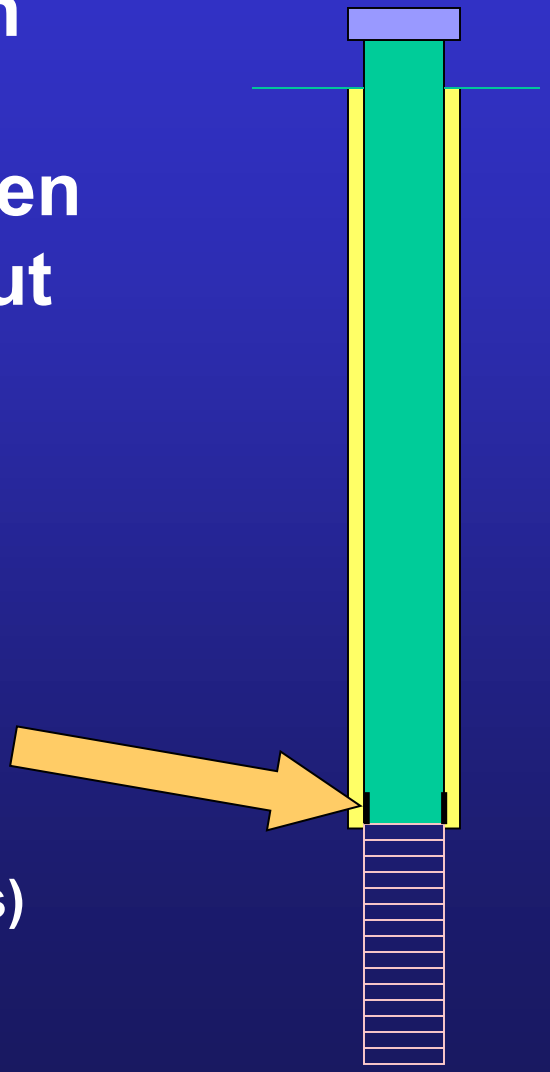
OVERLAPPING

SEALED TIGHTLY TO CASING

SCREENED AIR VENT

TIGHT SEAL TO ELECTRICAL CONDUIT

Device that seals space between casing & telescoped screen to keep sand out of well



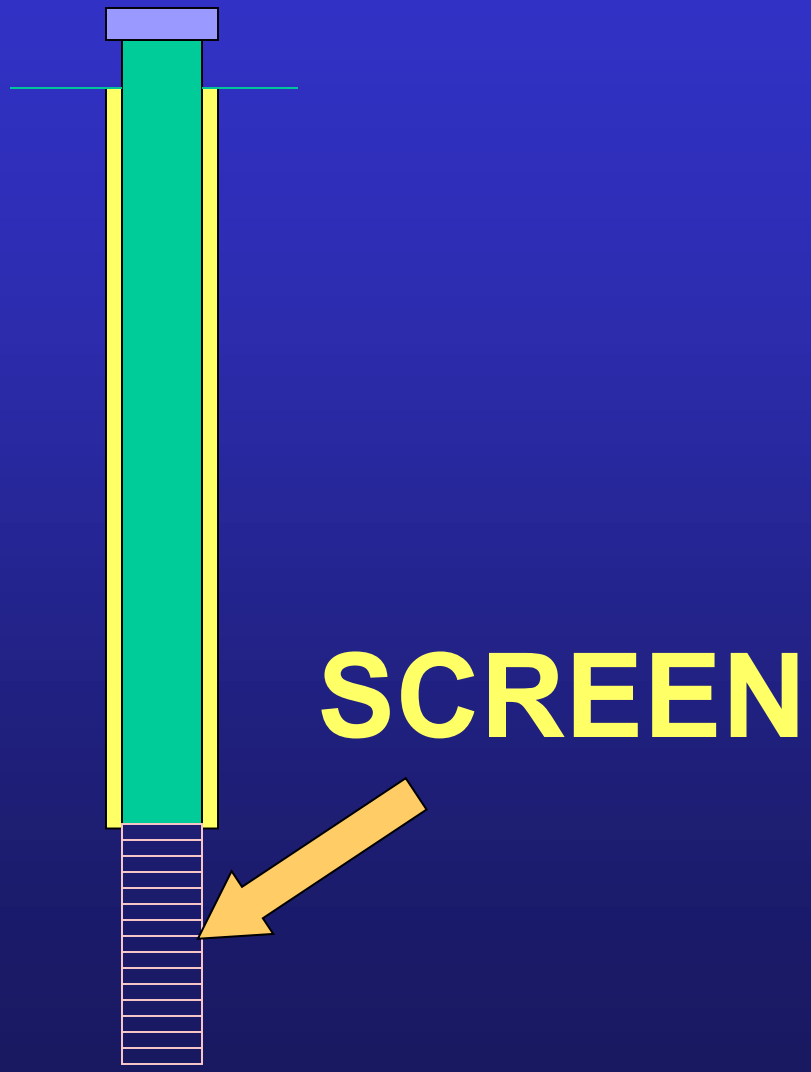
PACKER

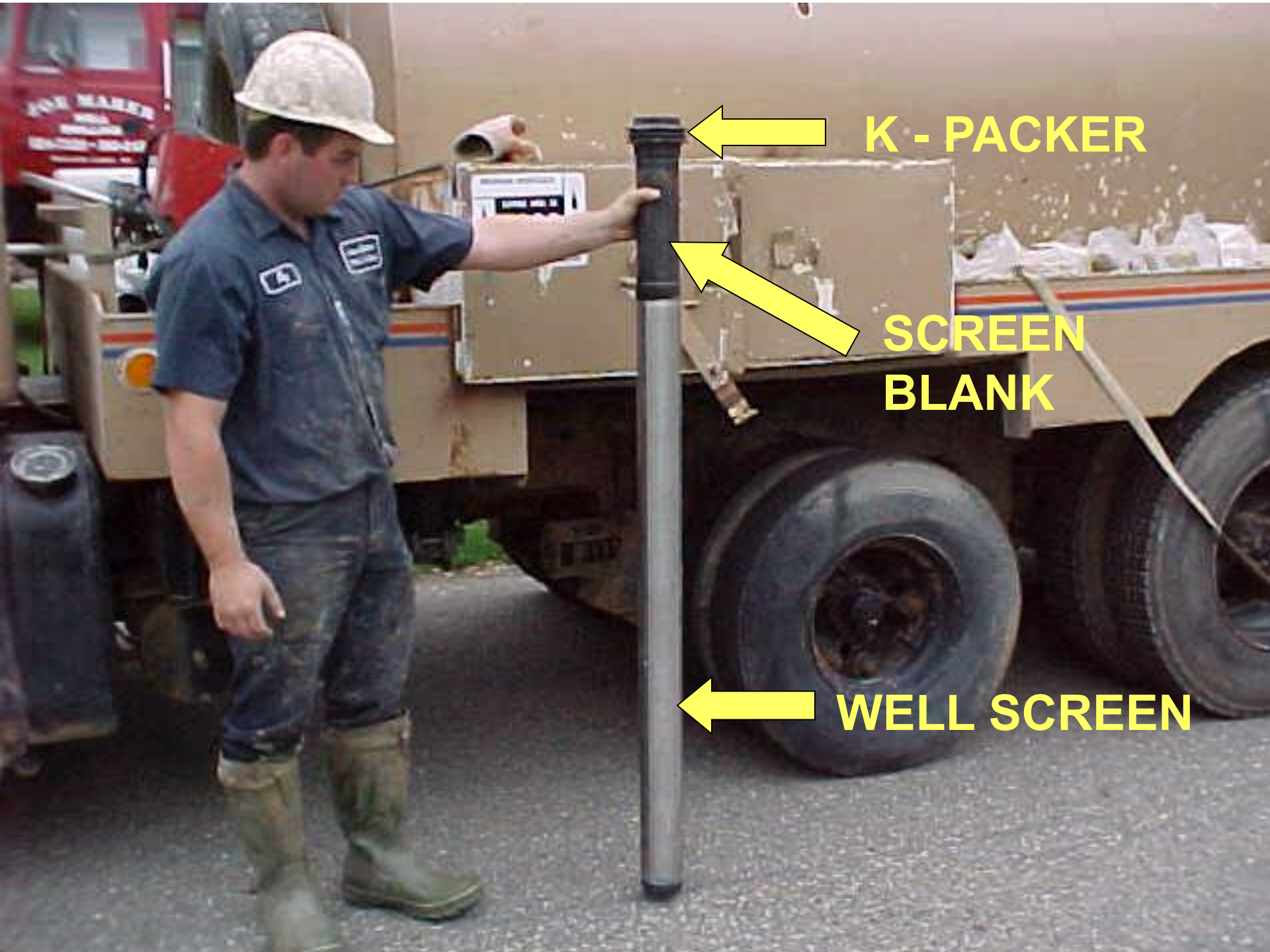
(Coupling with neoprene rubber flanges)

Intake device to allow water to enter well and keep sand out

Structural support of aquifer material

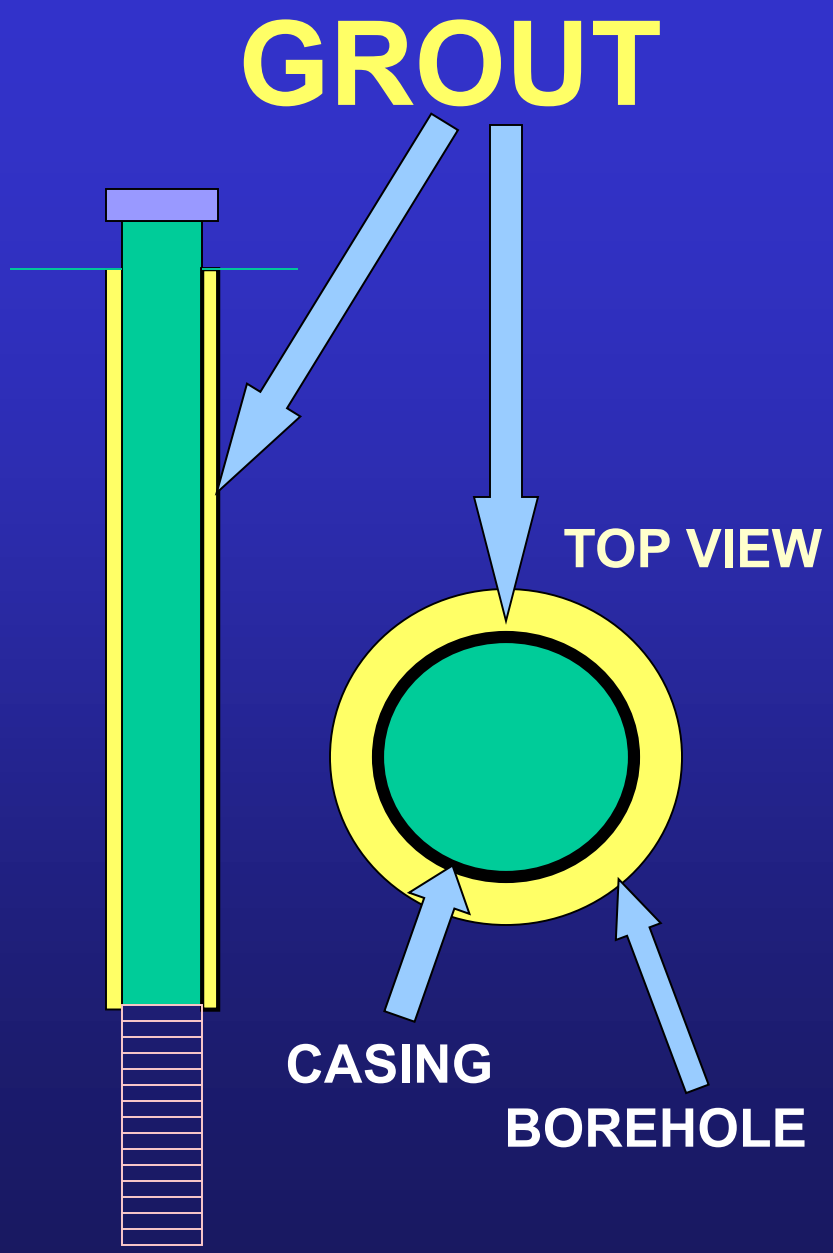
Wire-wrapped screen most common



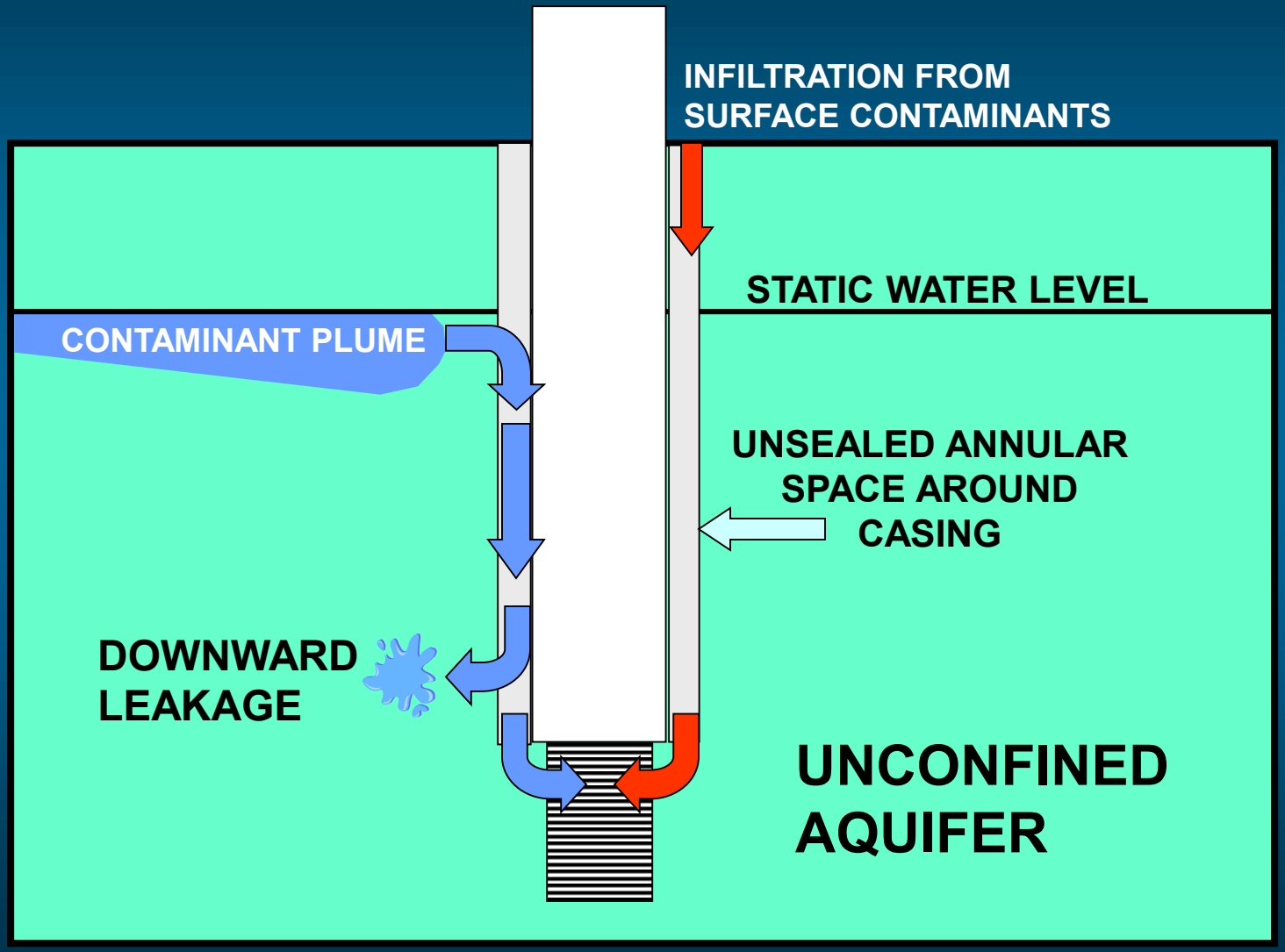

K - PACKER
SCREEN
BLANK
WELL SCREEN

Impermeable cement or bentonite clay slurry placed in annular space between borehole and casing to:

- prevent well contamination
- maintain separation of aquifers
- preserve artesian aquifers

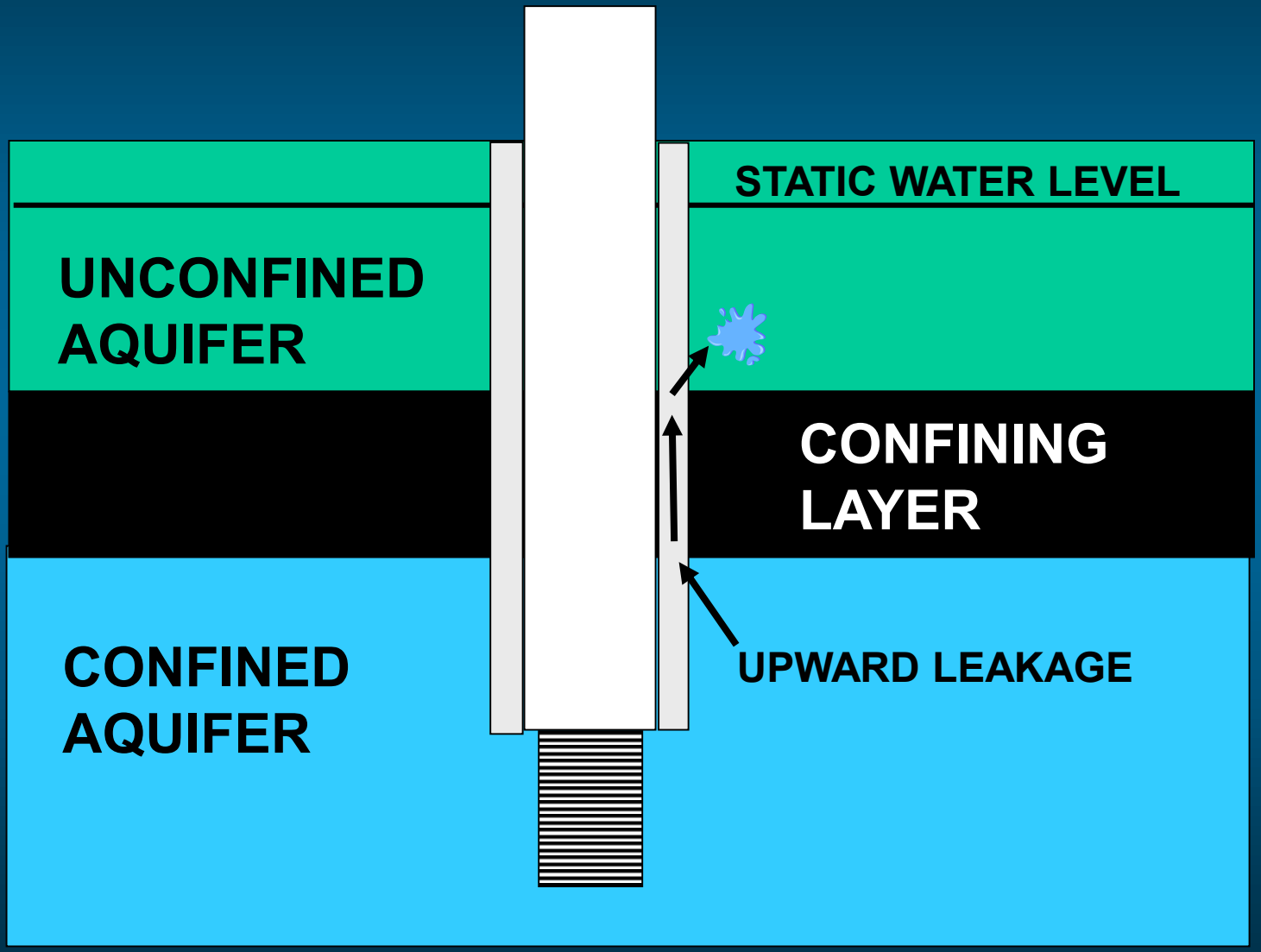


DOWNWARD LEAKAGE AROUND UNGROUTED CASING



UPWARD LEAKAGE AROUND UNGROUTED CASING

(Artesian Condition)



BENEFITS OF WELL GROUTING

- ***PREVENT CONTAMINANT MIGRATION FROM SURFACE (Keeps surface runoff from moving downward along well casing)***
- ***SEAL OFF POOR QUALITY AQUIFERS (Prevents mixing of water from different aquifers)***
- ***PRESERVE ARTESIAN AQUIFER PROPERTIES***
- ***ADDED SEALING OF CASING JOINTS***

WELL GROUTING MATERIALS

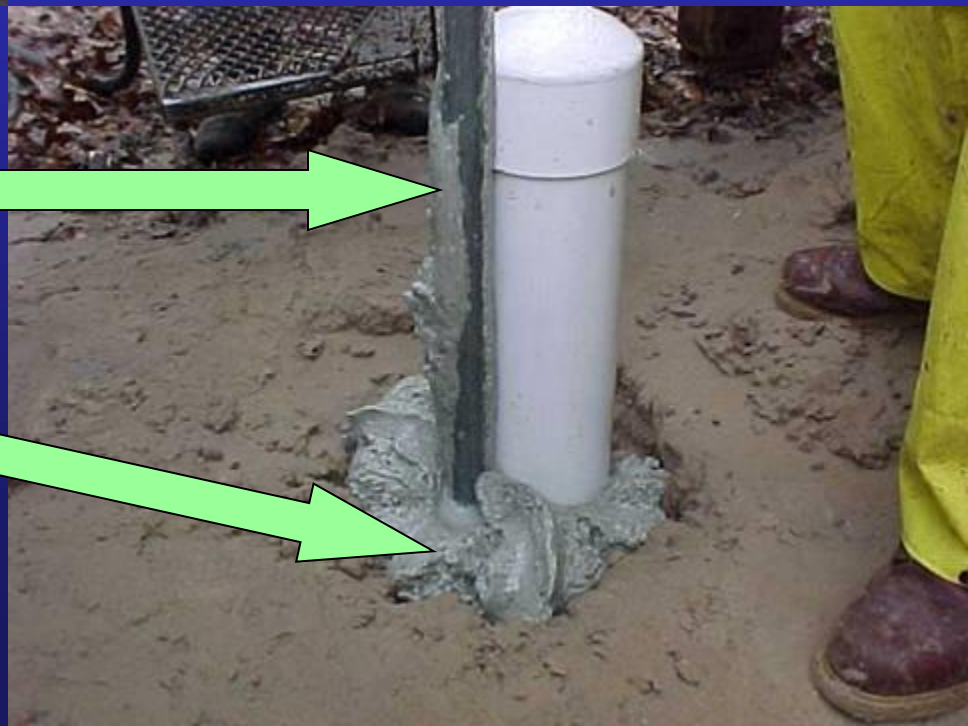
TYPE	*COMPOSITION*	*CHARACTERISTICS*
BENTONITE SLURRY	POWDERED BENTONITE & WATER GRANULAR BENTONITE, POLYMER & WATER	▪FLEXIBLE LOWER STRENGTH SEAL ▪MAY SUBSIDE IN VADOSE ZONE ▪MOST POPULAR DUE TO LOWER COST AND TARGETED MARKETING ▪WASH-OUT UNDER ARTESIAN PRESSURE ▪NO HEAT OF HYDRATION
NEAT CEMENT	PORTLAND CEMENT & WATER	▪MORE WIDELY USED IN OIL FIELD THAN WATER WELLS ▪HIGHER STRENGTH RIGID SEAL ▪BEST CHOICE FOR BEDROCK WELLS & FLOWING WELLS ▪HEAT OF HYDRATION & MICROANNULUS CONCERNS
CONCRETE GROUT	PORTLAND CEMENT, SAND & WATER	▪MORE PERMEABLE THAN NEAT CEMENT GROUT ▪MORE DIFFICULT TO PUMP (ABRASIVE) ▪GOOD CHOICE FOR LARGE DIAMETER WELLS

GRANULAR BENTONITE
POURED INTO
MIX WATER

PORTABLE
GROUTING MACHINE
(MIXER & PUMP)

GROUT PIPE
TO BOTTOM OF
ANNULAR SPACE

BENTONITE GROUT
RETURN
AT SURFACE
(GELATIN – OATMEAL TEXTURE)



WELL GROUTING

ROTARY *VS.* *CABLE TOOL*

GROUT PIPE IN ANNULAR SPACE

WELL CASING IN OVERSIZED BOREHOLE

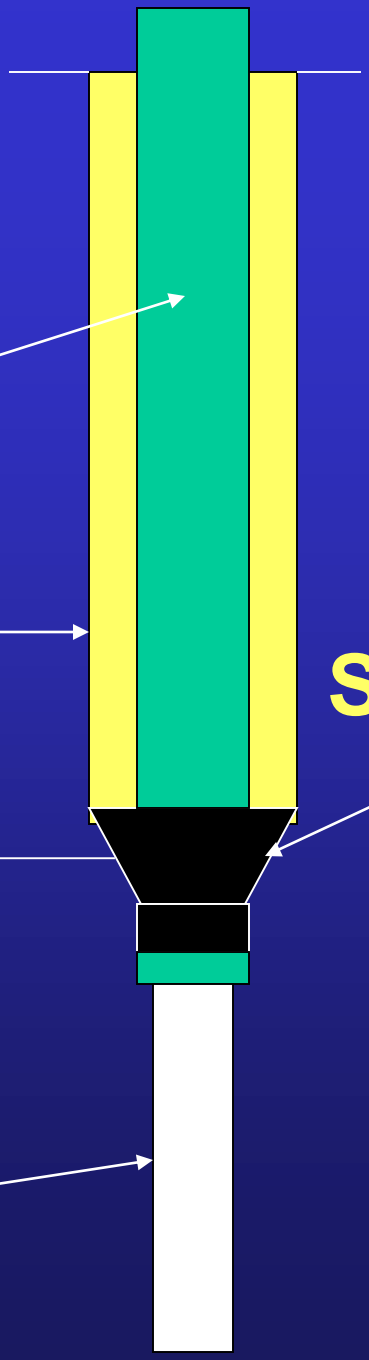
GROUT PUMPED FROM BOTTOM

DRY GRANULAR BENTONITE POURED AROUND CASING

GROUT FOLLOWS DRIVE SHOE AS CASING IS DRIVEN

- DEPTH OF GROUT TRAVEL IS UNCERTAIN
- LIMITED BY HIGH WATER TABLE

BEDROCK WELL DETAILS



CASING PIPE

GROUT

TOP OF BEDROCK

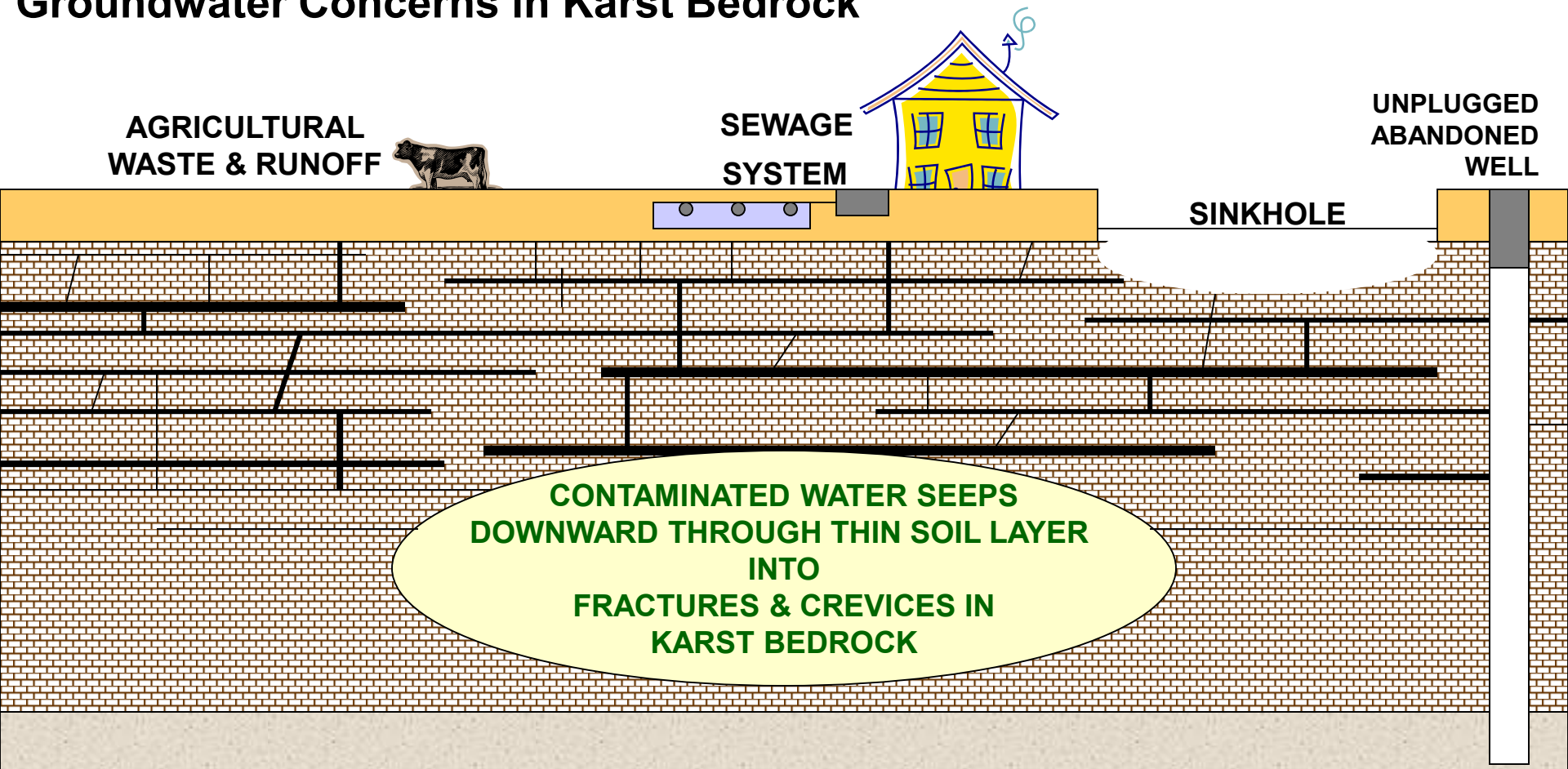
BEDROCK BOREHOLE (SMALLER DIAMETER THAN CASING)

SHALE TRAP OR SHALE PACKER

PREVENTS GROUT SPILLAGE INTO BEDROCK BOREHOLE

BETTER SEAL AT BEDROCK INTERFACE

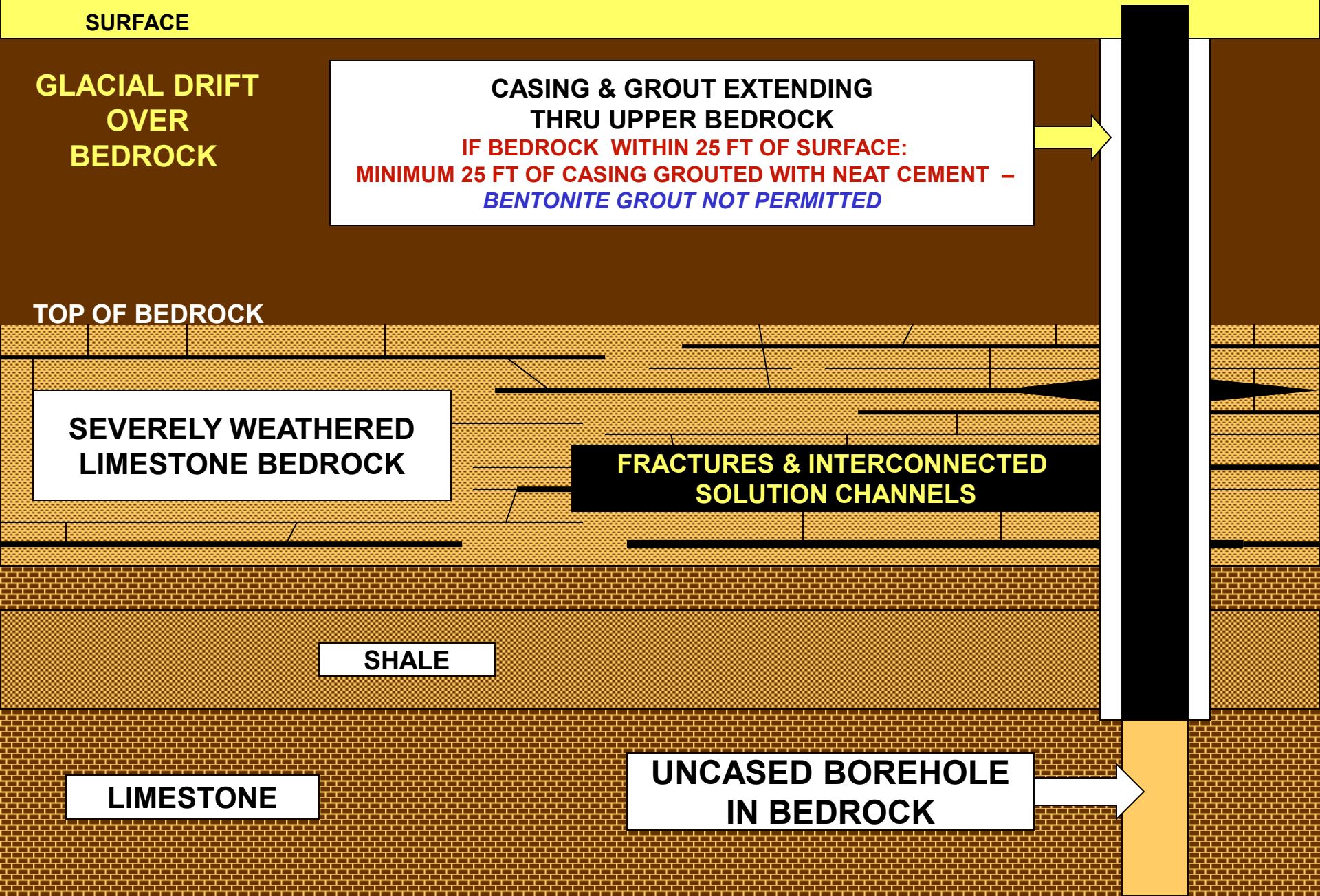
Groundwater Concerns in Karst Bedrock



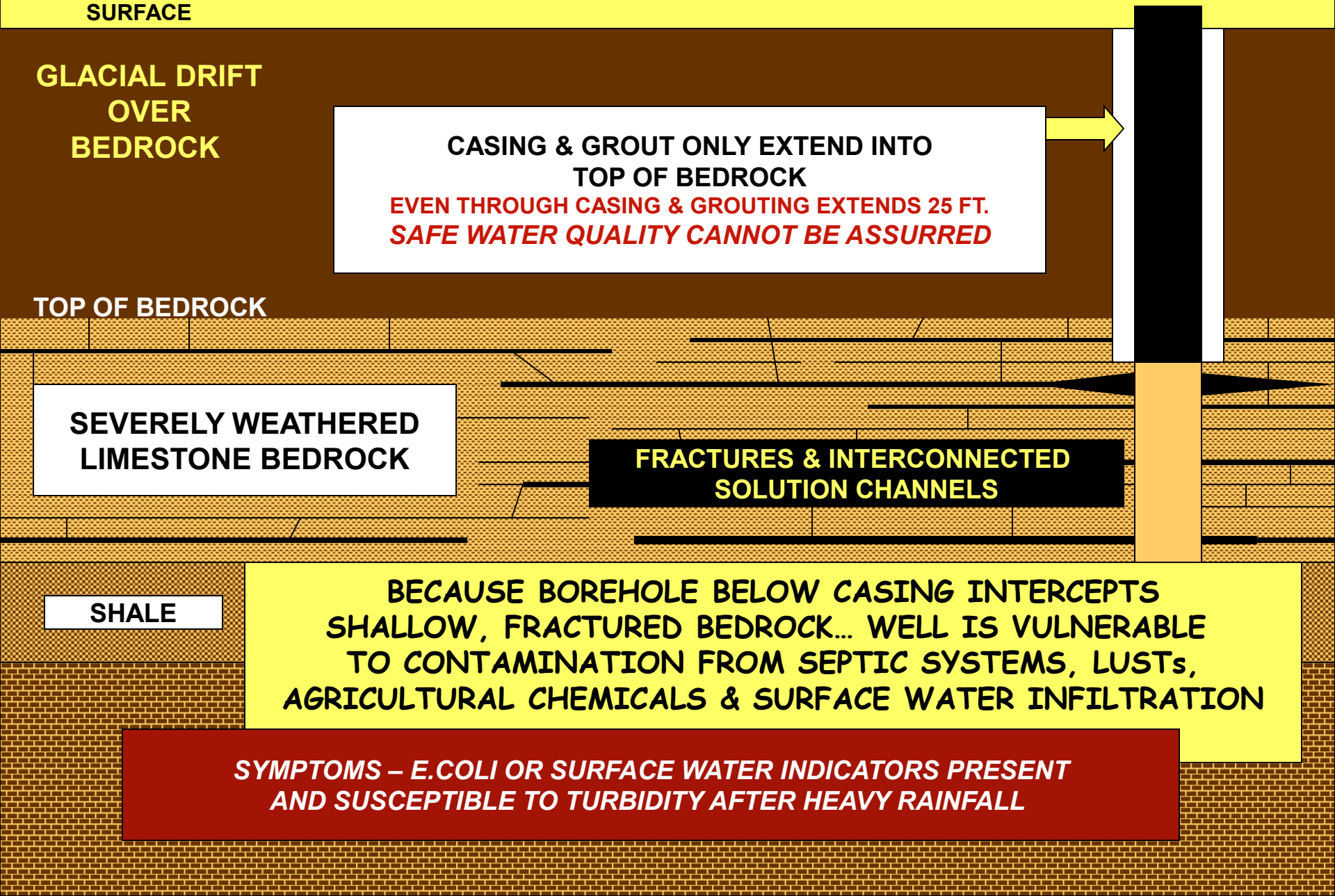
SIGNIFICANT RAINFALL OVER SHALLOW CARBONATE BEDROCK CAN CAUSE:

- ***SURGE IN WATER LEVELS (Increases hydraulic pressure)***
- ***INCREASED SURFACE WATER-TO-GROUNDWATER INTERCHANGE***
- ***FLUSHING OF TURBIDITY & ORGANIC MATTER INTO GROUNDWATER***

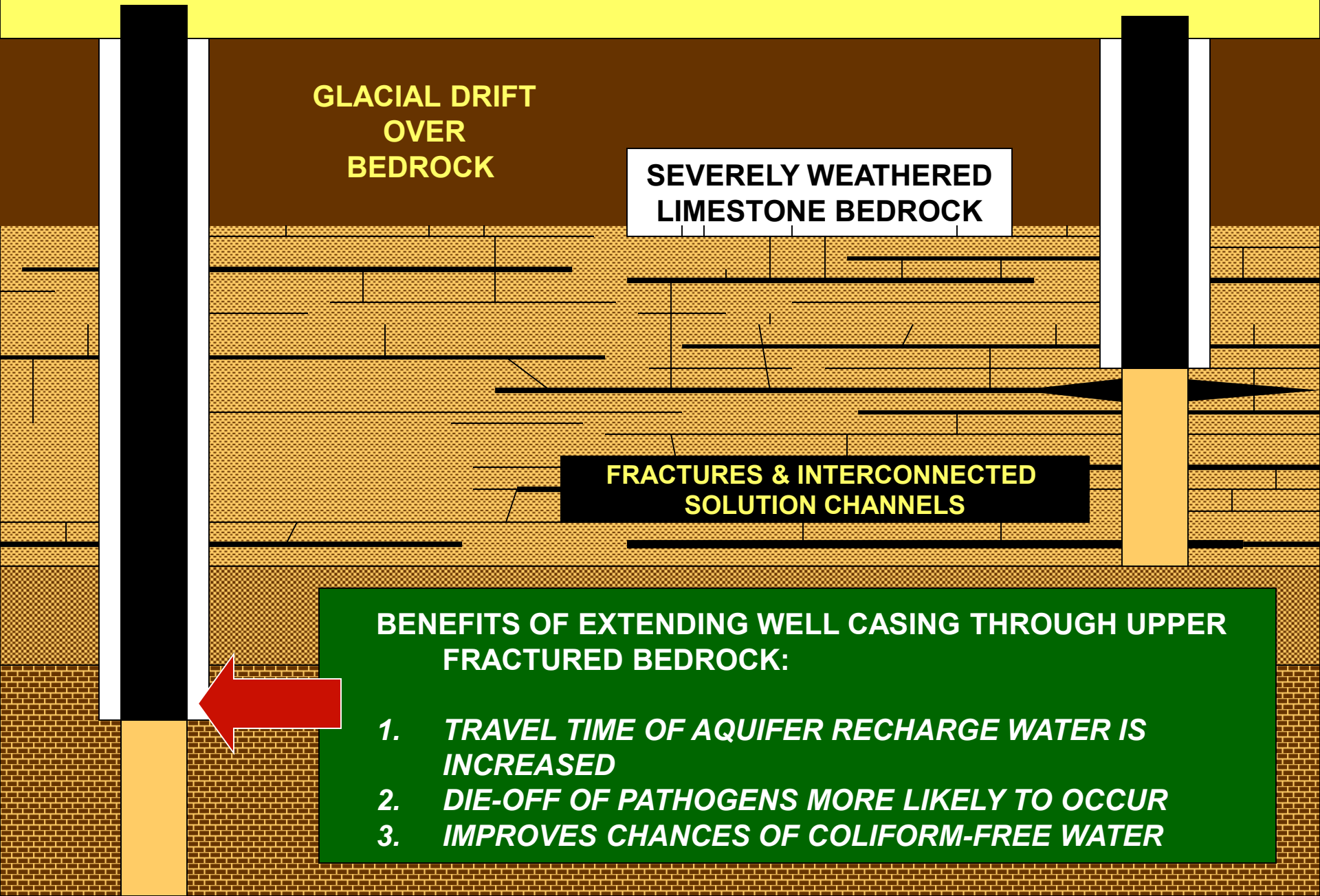
PROPER WELL CONSTRUCTION IN KARST



POOR WELL CONSTRUCTION IN KARST

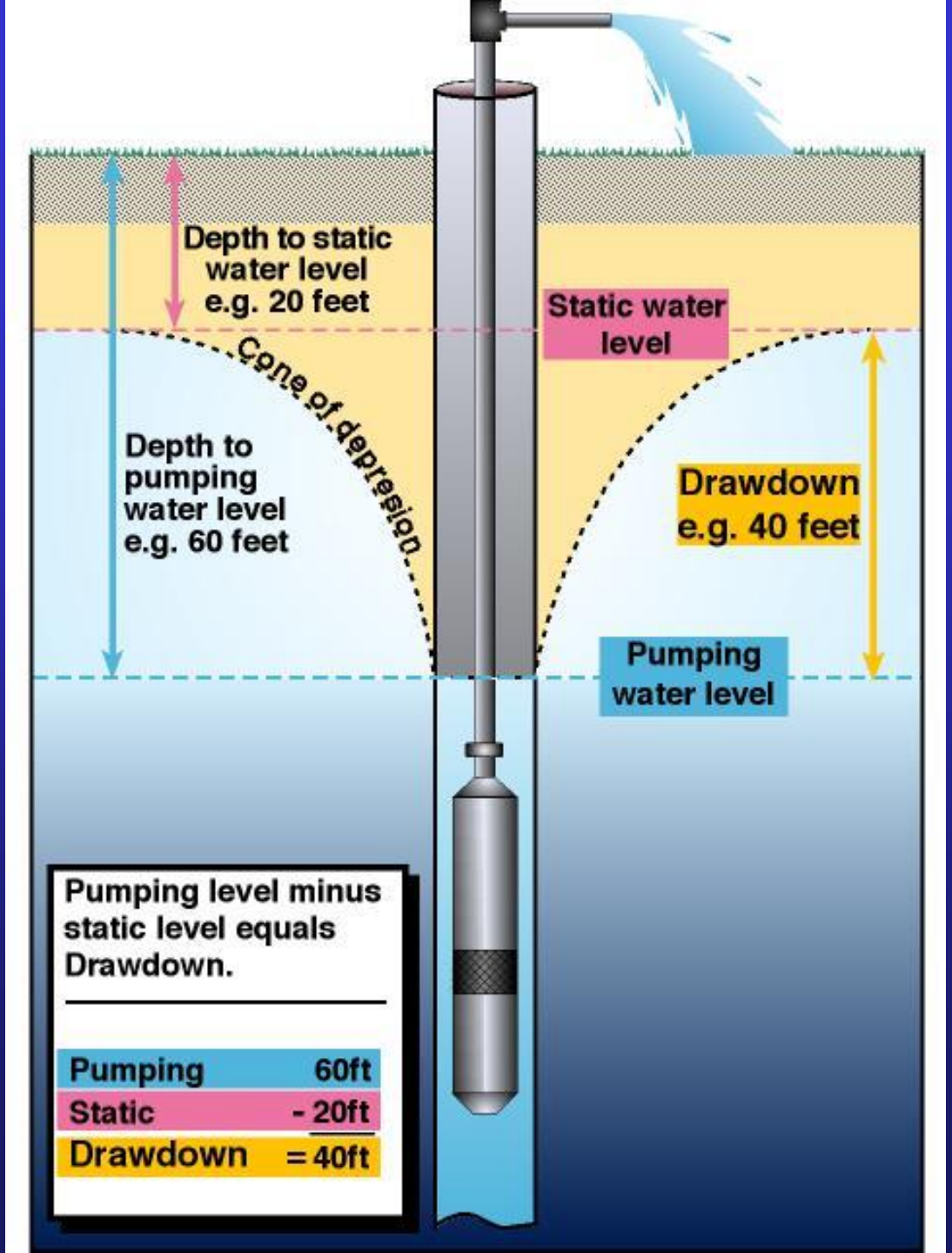


WELL CASING DEPTH IN KARST



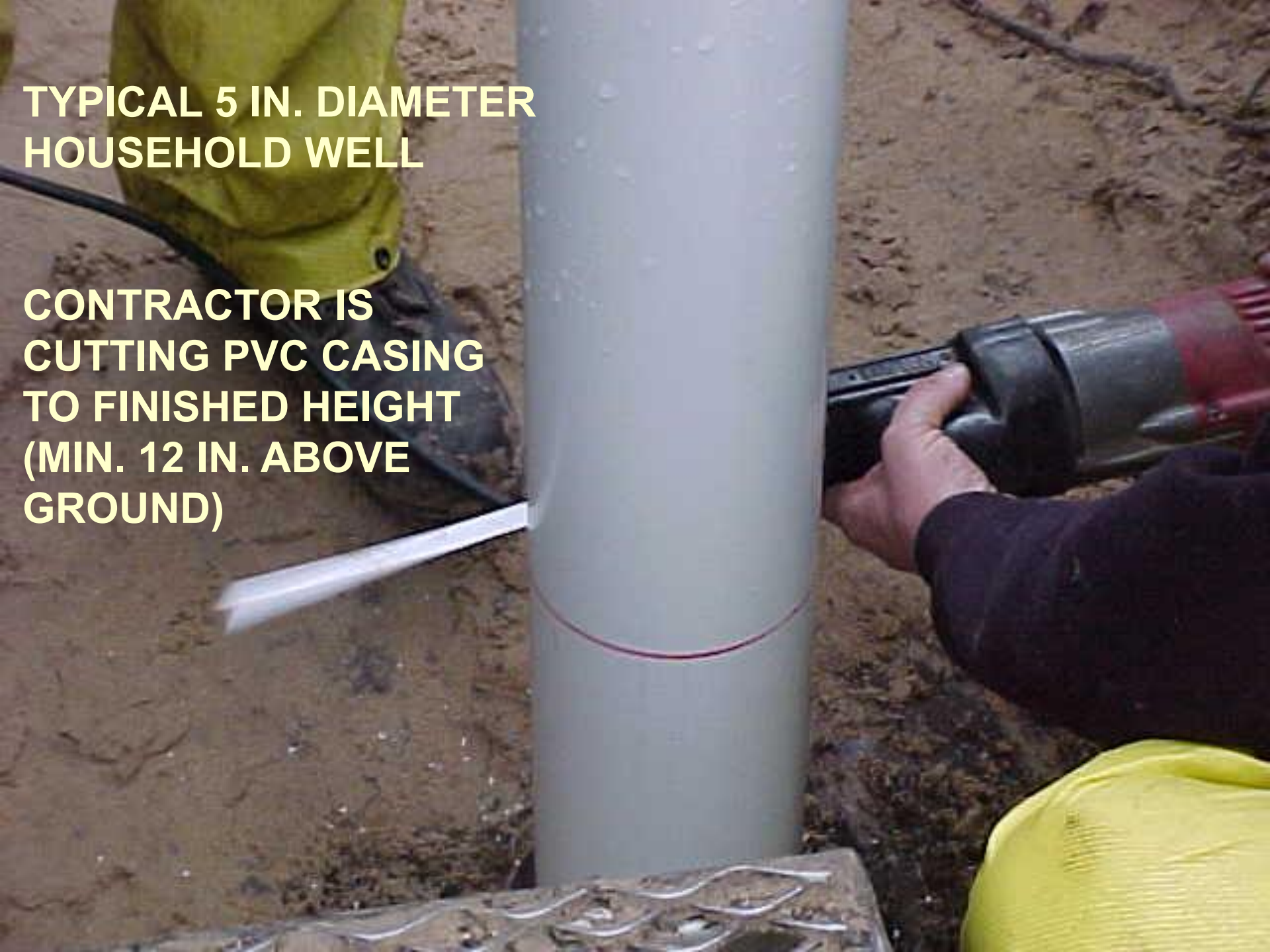
BENEFITS OF EXTENDING WELL CASING THROUGH UPPER FRACTURED BEDROCK:

1. *TRAVEL TIME OF AQUIFER RECHARGE WATER IS INCREASED*
2. *DIE-OFF OF PATHOGENS MORE LIKELY TO OCCUR*
3. *IMPROVES CHANCES OF COLIFORM-FREE WATER*


Depth to static water level e.g. 20 feet
Static water level
Cone of depression
Depth to pumping water level e.g. 60 feet
Drawdown e.g. 40 feet
Pumping water level
Pumping level minus static level equals Drawdown.
Pumping 60ft
Static - 20ft
Drawdown = 40ft

CASING MATERIALS COMPARISON

PVC PLASTIC	VS.	STEEL
Non-corroding		Corrodes
Lower strength		Higher strength
Fewer water quality complaints		Rusty water
Rotary construction only		Suitable for any drilling method
1/3 cost of steel		No heat of hydration impact from cement grout
SDR 17 needed past 200 ft.		


TYPICAL 5 IN. DIAMETER HOUSEHOLD WELL
CONTRACTOR IS CUTTING PVC CASING TO FINISHED HEIGHT (MIN. 12 IN. ABOVE GROUND)

WELL DIAMETER:

MYTH

Doubling well diameter appreciably increases well yield

FACT

DOUBLING WELL DIAMETER

10% YIELD INCREASE

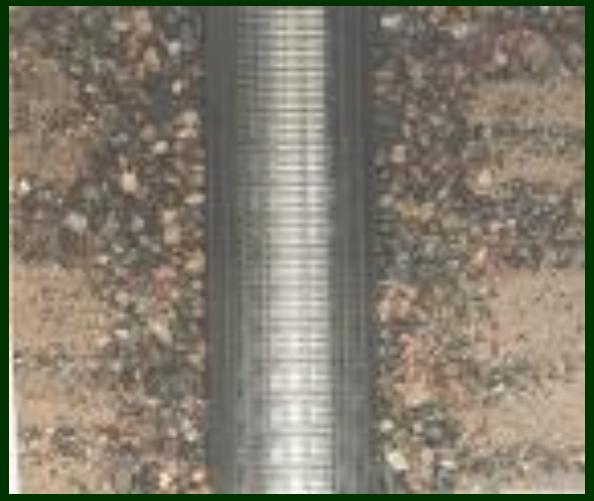
DOUBLING SCREEN LENGTH

DOUBLES WELL YIELD

SCREENED WELLS

Naturally Developed

WELL SCREEN SET IN NATIVE GEOLOGIC MATERIALS (SAND OR GRAVEL)



Filter Packed

(a/k/a Gravel-Packed)

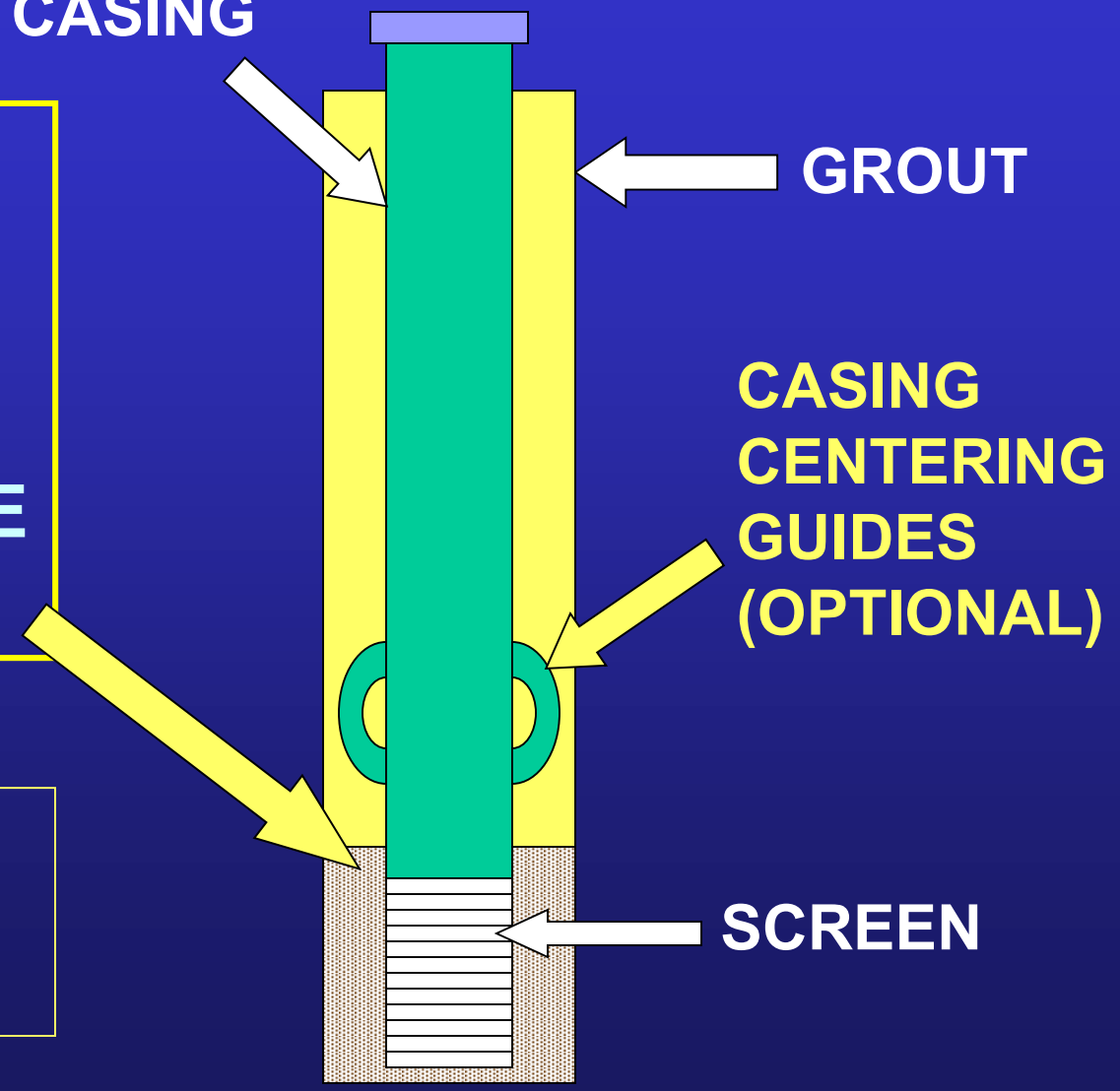
GRADED-WASHED SAND PLACED OUTSIDE WELL SCREEN

FILTER - PACK

BENEFITS

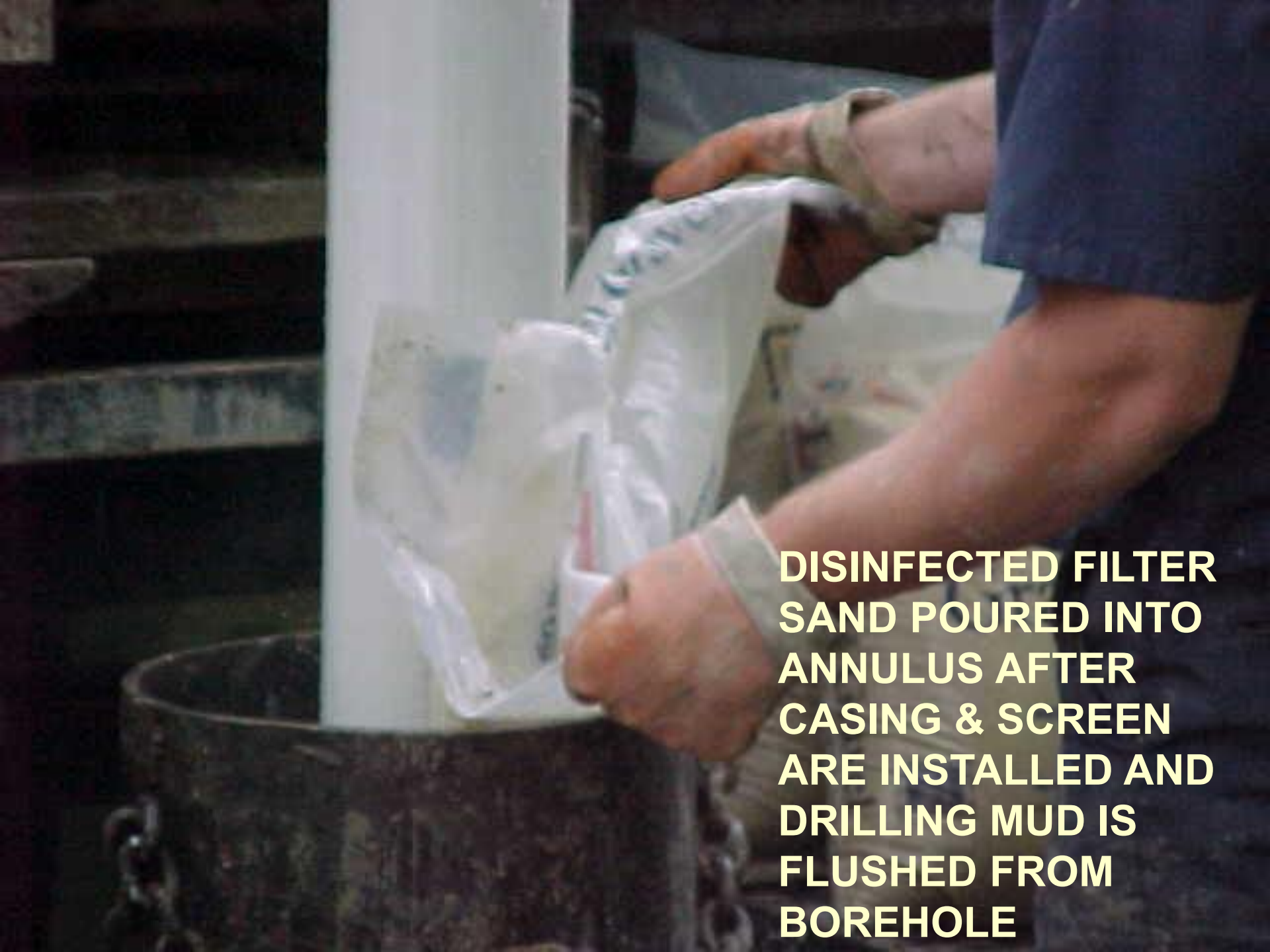
- Greater porosity
- Higher hydraulic conductivity
- Reduced drawdown
- Higher yield
- Reduced entrance velocity
- Faster development
- Easier grouting
- Longer well life
- Improved well rehabilitation
- Reduce sand pumping

FILTER-PACKED WELL CONSTRUCTION



FILTER-PACK SAND PLACED BETWEEN BOREHOLE & SCREEN BEFORE GROUTING

FILTER PACK IS NOT ALLOWED TO EXTEND MORE THAN 10 FEET ABOVE TOP OF SCREEN



DISINFECTED FILTER SAND POURED INTO ANNULUS AFTER CASING & SCREEN ARE INSTALLED AND DRILLING MUD IS FLUSHED FROM BOREHOLE

WELL SCREEN SELECTION CRITERIA

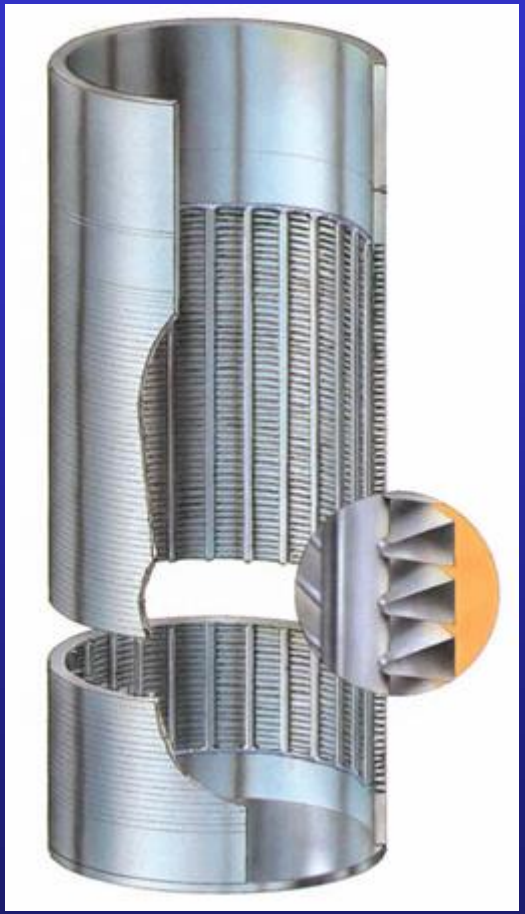
- **Maximize % open area**

BEST	WORST
CONTINUOUS SLOT WIRE WOUND	SAW – CUT OR GAUZE-COVERED

- **Non-clogging openings**
- **Corrosion resistance**

  STAINLESS STEEL vs. PVC PLASTIC

- **Column & collapse strength**



SCREEN SELECTION CRITERIA

Screen opening size based on aquifer material size:

SIEVE ANALYSIS vs. S.W.A.G.

NATURALLY-DEVELOPED WELL:

40% RETENTION OF AQUIFER MATERIAL

FILTER-PACKED WELL:

90% RETENTION OF FILTER SAND

Screen diameter: BASED ON CASING SIZE

PROVIDE WATER ENTRANCE VELOCITY OF…

<0.1 FT./SEC.

MINERAL INCRUSTATION

Lower velocity reduces mineral incrustation

EXTENDS WELL SERVICE LIFE

ENTRANCE VELOCITY = PUMPING RATE / SCREEN OPEN AREA

Example: 6 in. Pipe Size X 8 ft. length

10 slot Continuous slot SS

Pumping rate = 75 GPM

Screen open area (from manufacturer) = 0.21 ft^2/lin ft

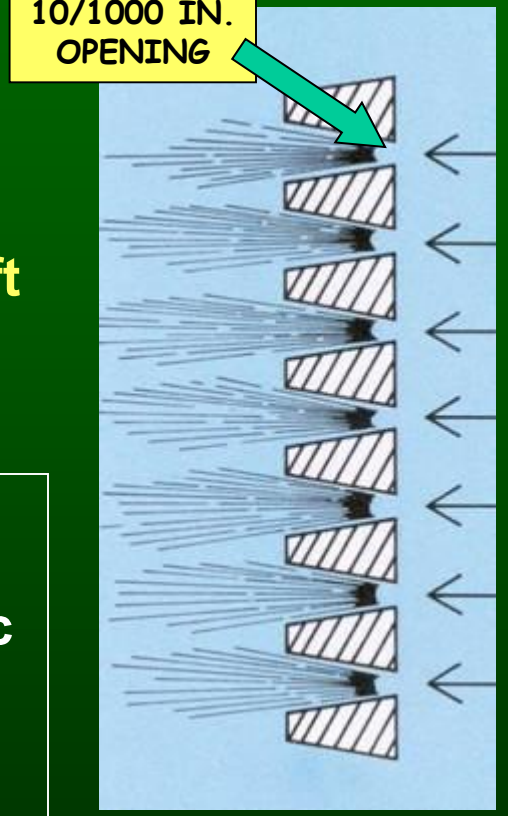
Total screen area = 8 ft x 0.21 ft^2/lin ft = 1.68 ft^2

CONVERT GPM TO FT^3/SEC

75 GPM x 1 ft^3/7.48 gal x 1 min/60 sec = 0.167 ft^3/sec

0.167 ft^3/sec / 1.68 ft^2 = 0.099 ft/sec

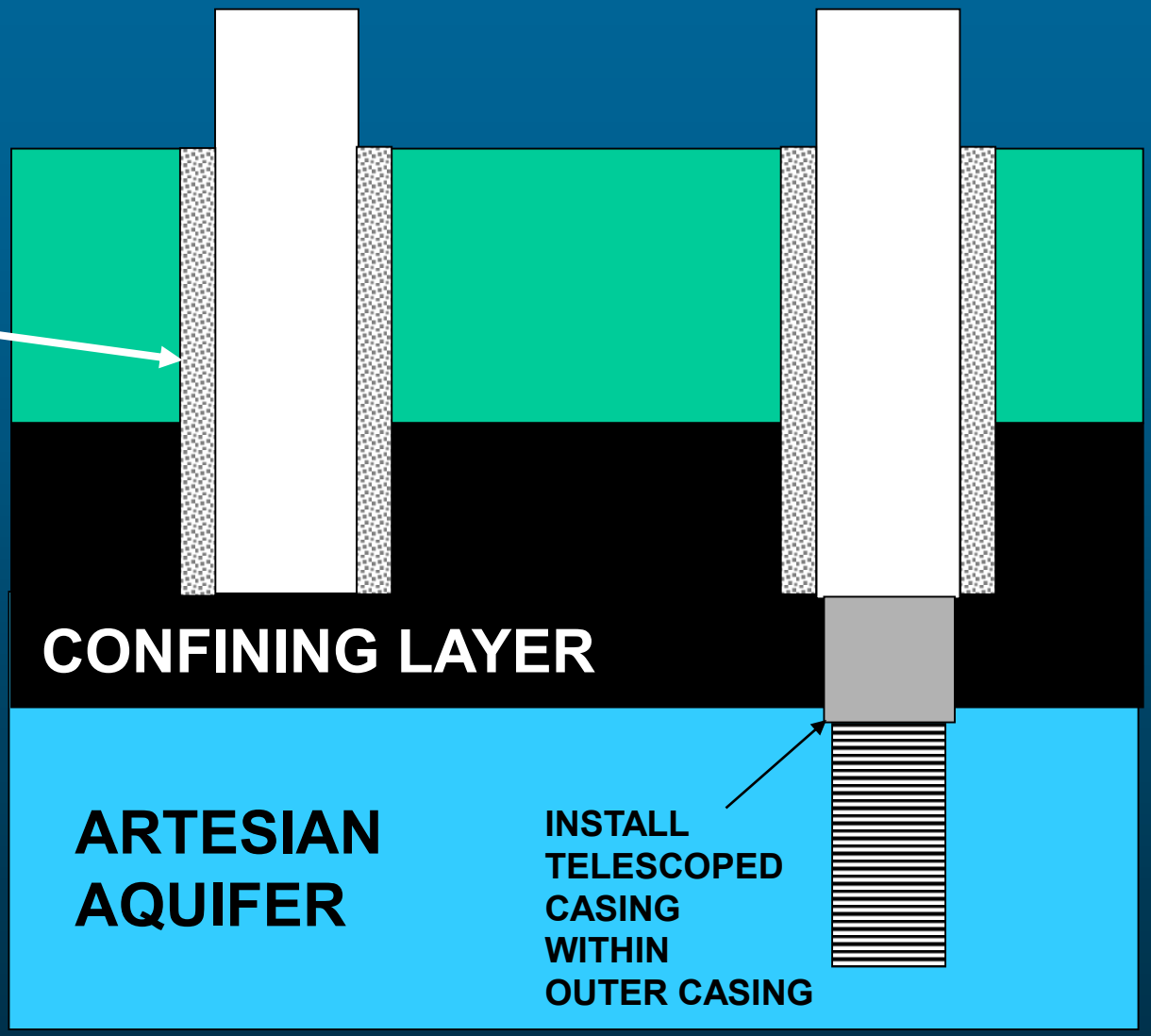
Is an entrance velocity of 0.099 ft/sec acceptable?



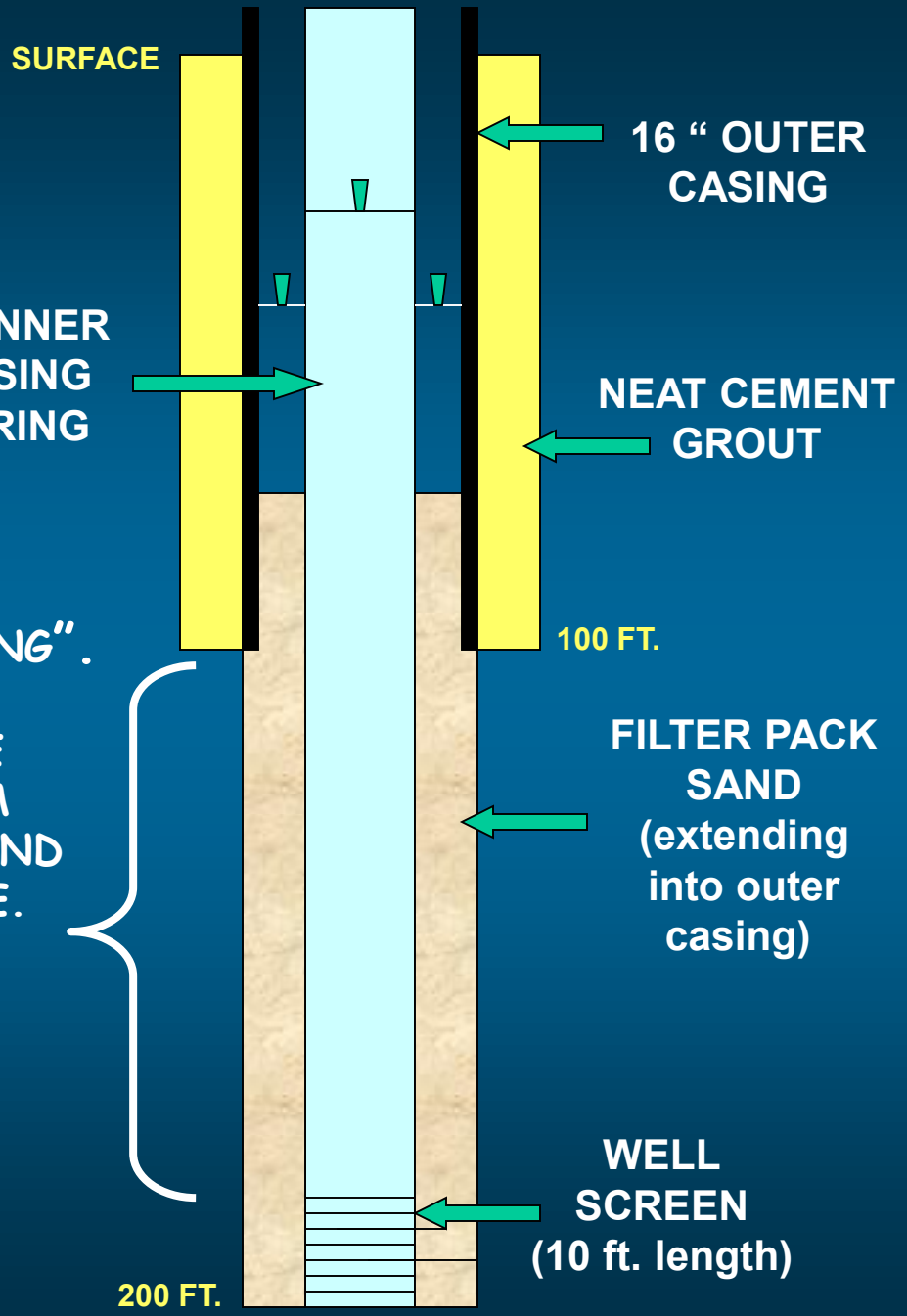
CROSS-SECTION OF SCREEN WIRE

IN KNOWN FLOWING WELL AREAS:

CEMENT CASING INTO CONFINING LAYER <u>BEFORE</u> PENETRATING ARTESIAN AQUIFER



HIGH-CAPACITY WELL DESIGN CONCERNS



INNER CASING IS "PERMANENT CASING". WELL CODE REQUIRES GROUTING FROM NOT MORE THAN 10 FT. ABOVE SCREEN UP TO SURFACE – ZONE FROM 100 FT. TO 190 FT. IS UNGROUTED AND VIOLATES R 325.1634a OF WELL CODE.

PROBLEMS FROM THIS DESIGN MAY INCLUDE:

- ***COMMINGLING OF WATER FROM SEPARATE AQUIFERS***
- ***STAGNANT WATER IN FILTER PACK ABOVE SCREEN***


CLEAN WATER PUMPED
FROM WELL DURING
FINAL DEVELOPMENT
STAGE

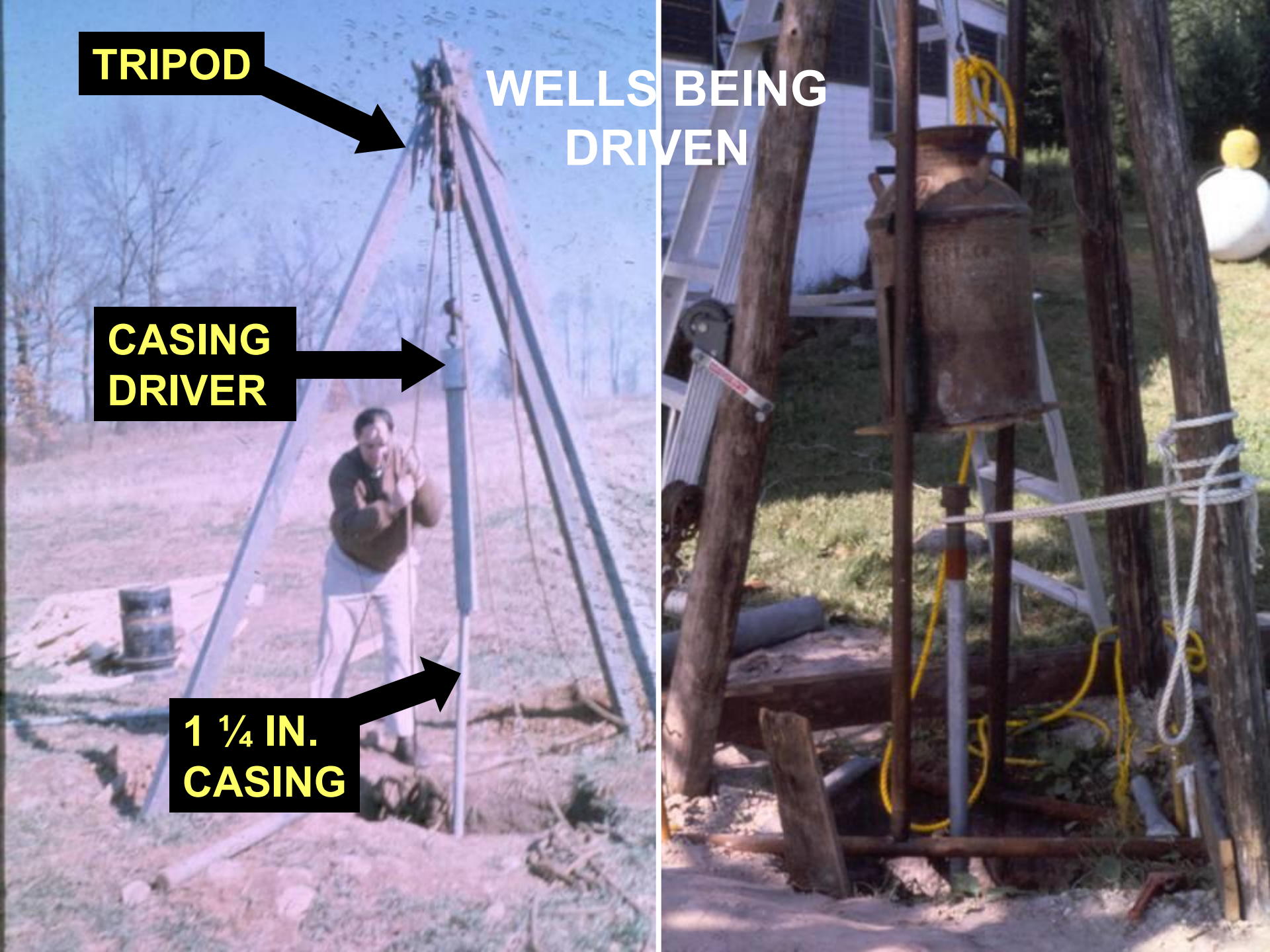
DRIVEN WELLS

- Installed in glacial drift only - CANNOT be driven thru boulders or into bedrock
- Well point driven into ground with post-driver, tripod w/ weight or sledge hammer
- 1 1/4 in. to 2 in. diameter

DRIVEN WELLS

- Installed by property owners
- Common around lakes and high water table areas
- Most <35 ft. deep, limited yield (7 gpm or less)

MORE SUSCEPTIBLE TO SURFACE CONTAMINATION THAN DRILLED WELLS


TRIPOD
WELLS BEING DRIVEN
CASING DRIVER
1 ¼ IN. CASING

DUG WELLS

- Large diameter (18-48 in.)
- Found in low yield areas (Thumb & SE Michigan)
- Casing material - concrete crocks w/ loose joints

  Older wells: stones, brick-lined
- Water enters well through loose casing joints


SHALLOW UNSANITARY DUG CROCK WELL


OLD UNSANITARY HAND-DUG WELL
LINED WITH FIELD STONE

DUG WELLS

- Older wells - hand dug
- Now installed (on very limited basis) w/ bucket augers (backhoes – phased out)
- Low well yield - storage in casing (100's of gallons)
- **HIGHLY VULNERABLE TO CONTAMINATION**

CDC Findings on Dug Wells

- **Dug/bored wells had a positive coliform bacteria rate of about 85%**

- **Wells with brick, concrete or wood casing (dug wells) had coliform positive rates of 60 – 90 %**

From *A Survey of the Presence of Contaminants in Water From Private Wells in Nine Midwestern States*, Atlanta, Georgia, U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, 1996

DUG WELLS

- **Needs LHD approval under R 325.1674 of well code….before installation**

30 in. diameter fiberglass casing (NSF Std. 61 listed) accepted by MDEQ for bucket auger wells

REPLACEMENT FOR CONCRETE CROCKS

Water Quality in the New World

In 1610, Jamestown's Governor proclaimed:

"There shall be no man or woman dare to wash any unclean linen, wash clothes, … nor rinse or make clean any kettle, pot or pan, or any suchlike vessel within 20 feet of the old well or new pump. Nor shall anyone foresaid within less than quarter mile of the fort, dare to do the necessities of nature, since by these unmanly, slothful, and loathsome immodesties, the whole fort may be choked and poisoned."

REMEMBER…..

ALWAYS DRINK UPSTREAM OF THE HERD

Contact DEQ Well Construction Program
at 517-241-1380