
GLOBAL SM
GREEN LIFTS
Changing The Way Water Moves

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I & I

Inflow of rain water and Infiltration of under ground water into sewer system

BY

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GLOBAL GREEN LIFT

Effect of "I & I" on sewer system

- Serious
- Unhealthy
- Costly

A- System flow operation

- Inflow
  - Even though is insignificant to total "I & I" it creates surge in sewer handling system of laterals, gravity pipes, manholes, and lift-stations.
  - Sewer system delivers with its max. Capacity flow to treatment plant, the excess flow will over flow from manholes' lids into streets, and contaminates its way

Effect of “I & I” on sewer system

B- Treatment plant’s capacity

- Capacity of the plant is designed based on the expected waste water from customers, and its expected life span (for example 30 years)
- If the plant, is designed to operate with 50% of its capacity by the 10th year, and remaining 50% is left for future growth in (next 20 years)
- A few settlements of large gravity pipes in the first 10 years can add an additional flow of 50% of I & I and will demand 100% of the plants capacity leaving no room for future development and growth.
- Urgent capital will be needed for plant expansion or new plant

Effect of "I & I" on sewer system

C- Sewer system's operating cost

- The operating cost of waste water from customers to injection wells varies by city, ranging from $1.16/1000g in Salt lake city to $ 17.38/1000g in Atlanta.
- Residential rate for city of Ft. Lauderdale is $5.07/1000g with an annual growth rate of 5%
- about 50% of this cost is due to I & i
- 50% of annual running cost of sewer system is for "I & I"
- by elimination of "I & I", system's **running energy** will be reduced to **50%**

IS “ I & I “ DETECTABLE ?

YES & NO

YES : Inflow is detectable and measurable. It is responsible for less than 0.5% of total “I & I” and its shows as flow surge in the entire sewer system

NO : Continuous Infiltration of underground water is invisible & undetectable, it is responsible for about 99.6 % of total” “I & I”.

Total I&I can be accurately estimated!

1. Identify catch basins on city area map
2. In each catch basin, select minimum of five random houses with irrigation water meters
3. Find annual irrigation water for those houses, $Q_{(\text{ irr. })}$
4. Find landscape area of those houses, $A_{(\text{ land. s.})}$ in ft^2
5. From 3 & 4 above find annual water irrigation index

$$W_{(\text{ irr. Index})} = \frac{Q_{\text{ irr.}}}{A_{\text{ land. S.}}} \qquad (\text{GALLON}/\ 1000\ \text{Ft}^2)\ /\ \text{year})$$

Total I&I can be accurately estimated!

6. From aerial map, calculate the total landscape area irrigated by city's water, $A_{(T.\ land\ s.)}$ in Ft^2

7. Total irrigation water by city's water will be, $Q_{(T.\ irr.)} = A_{(T.\ land.\ s.)} \times W_{(irr.\ index)}$ in gallons/year

8. $Q_{(flush)}$, is the annual water flush out by hydrant flushing, for water system cleaning

9. $Q_{(real\ sewer)} = Q_{(water\ system)} - Q_{(flush)} - Q_{(T.irr.)}$ R. sewer ,gal./year

10. $Q_{(T.I\ \&\ i)} = Q_{(periodic\ rain)} + Q_{(continuous\ under\ ground)}$

11. $Q_{(T.I\ \&\ i)} = Q_{(pant\ inflow)} - Q_{(real\ sewer)}$

“ INFLOW “ PREVENTION ,

- Adding rubber gaskets to manhole lids (~$100/lid)
- community policing, for any water dumping into manholes or connection of storm drain to sewer system

INFILTRATION,

- "Infiltration" is the intrusion of rain water or under ground water into sewer systems underground

- Infiltration can be classified as:
  - A- dry soil periodic rain water infiltration
  - B- wet soil periodic rain water infiltration
  - C- continuous under ground water infiltration

B- Coastal Cities:

- In coastal cities under ground water level is at the depth of 5’ to 15ft, and the majority of gravity sewer pipes are submerged in under ground water.
- Dry soil infiltration is noticeable during rain, specially when the ground is flooded and dry soil become saturated.
- The annual dry soil infiltration in coastal cities compare to total annual water intrusion is insignificant and is near 0.0 %

B-Wet soil periodic rain infiltration,

- Wet periodic rain infiltration refer to intrusion of rain water ,when u. g. water rises and more gravity pipes become submerged

- In this case, the net imposing water pressure is “h”. “h” is distance of the joint to under ground water table.

- This pressure head at the joint will convert to water velocity “ v “ and causes water to rush in to the pipe, that will show as flow surge in sewer plant

JOINT'S VELOCITY,

The water velocity at a joint's opening that is a distance h below the underground water level is given by:

$$V = (2g.h)^{1/2}$$

where;

V : is the water velocity at joint opening (ft/sec)

g : is gravity acceleration and is (32.2 ft/sec ^{2})

h : is water head (distance of joint to u. g. water (ft)

RUSH IN FLOW,

If the open joint has area of “A” (inch²), then the water infiltration by pressure of “h” in (ft), in Gpm will be;

$Q_{(gpm)} = 3.125\ V_{(ft/sec)} \times A_{(inch^2)}$

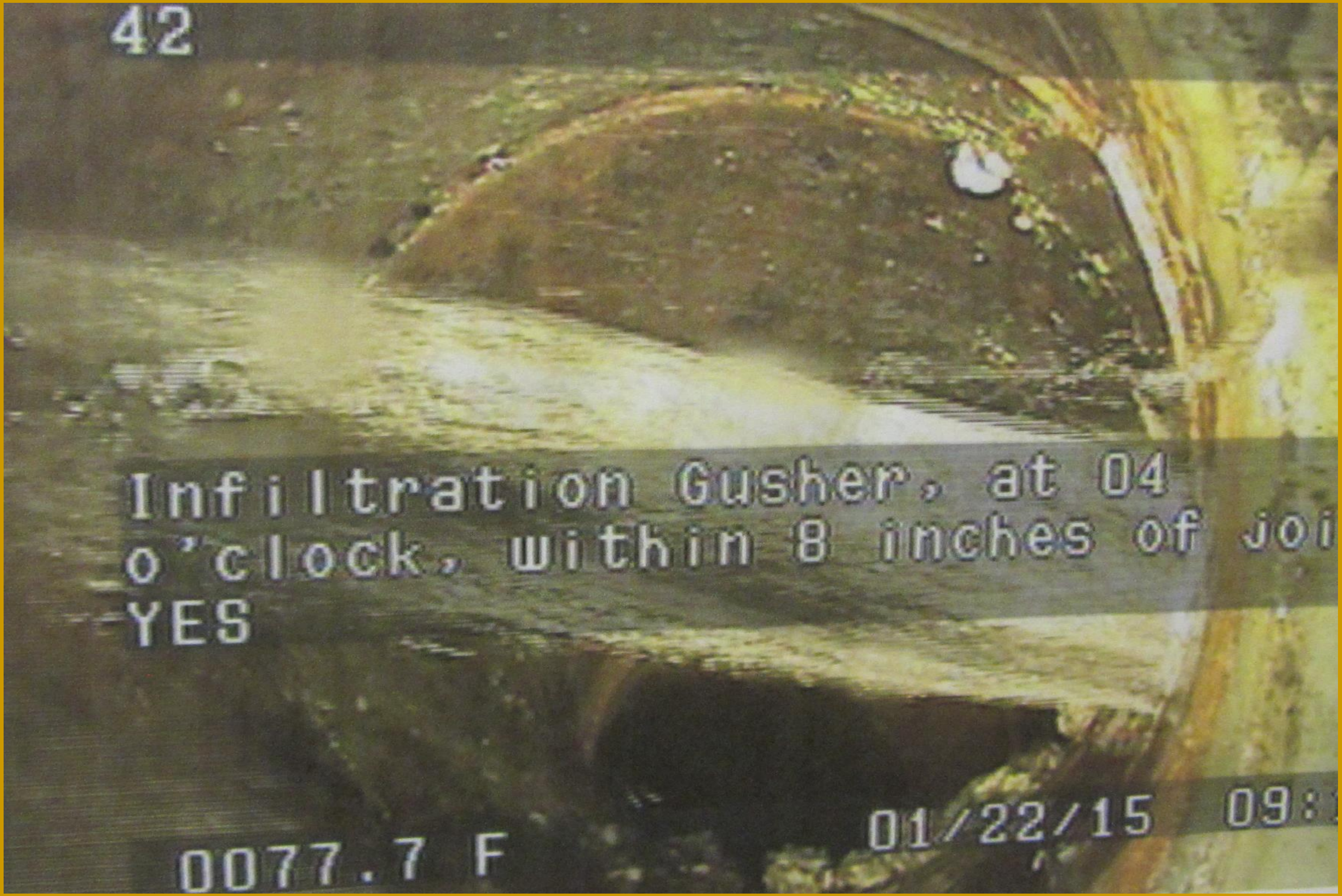
$Q_{(gpm)} = 25.08\ h^{1/2} \times A_{(inch^2)}$

Example:

$A = 1 inch^2$, $h = 4$ ft

$Q_{(gpm)} = 25.08 \times 4^{1/2} \times 1 = 50.16$ G.pm

Wet periodic infiltration has a delay of start about 2 to 3 hours in respect to rain start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SIGNIFICANCE OF WET PERIODIC RAIN IN COASTAL CITIES:

Periodic rain intrusion increases the sewer flow, it is detectable and can be measured

- In coastal cities, the total I&I from rain is the sum of:

  A- inflow

  B- dry soil water infiltration

  C- wet soil water infiltration

- Annual rain water "I&I", in compare to continuous u. ground water infiltration is insignificant (under 0.5 %)

“CONTINUOUS” INFILTRATION,

Happens only in coastal cities, where under ground water table is in depth of 4’ to 15 feet.

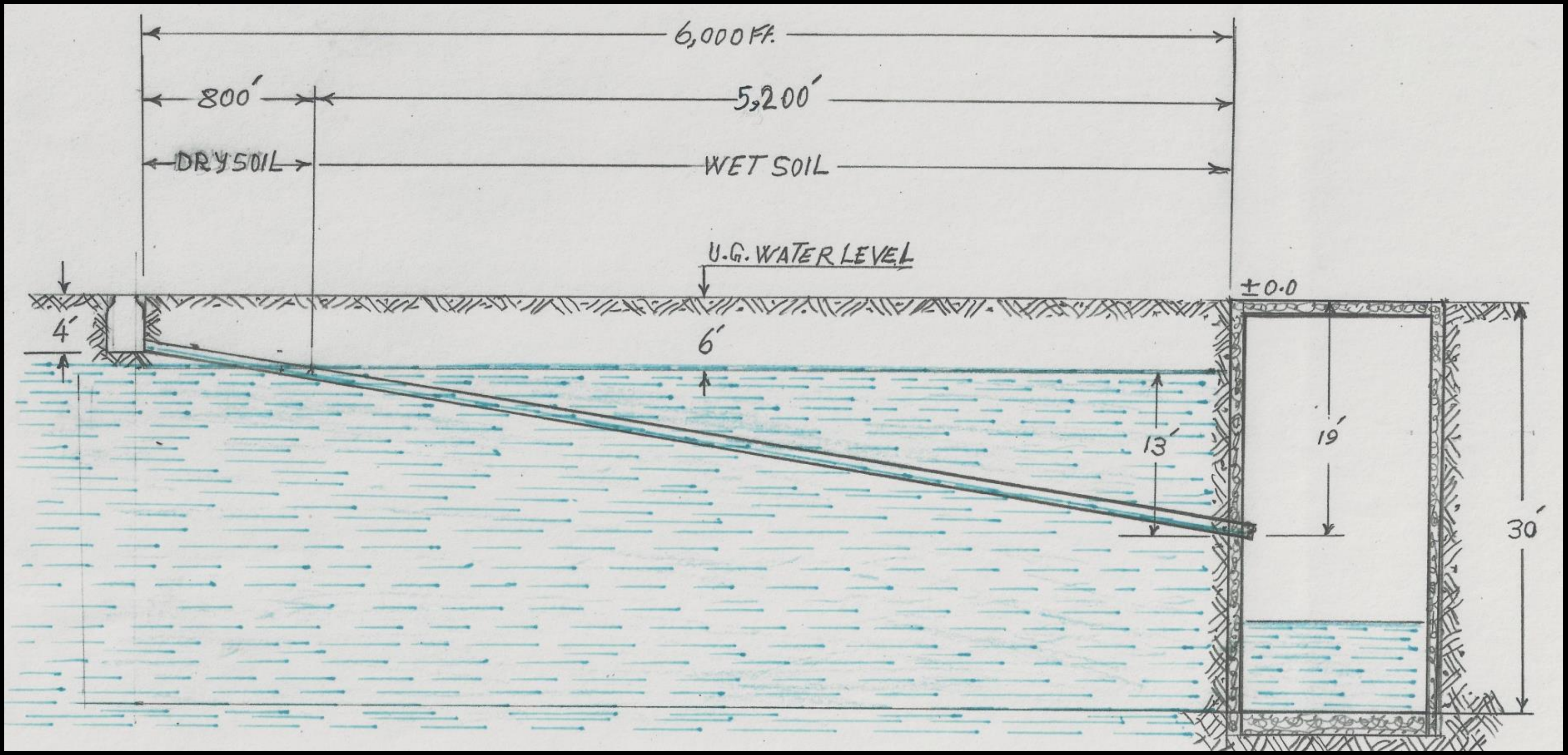
- 65-100 % of gravity sewer pipes are sub-merged, and 35-0 % of pipes are in dry soil
- Such sewer system is subjected to “Inflow”, “ dry periodic infiltration”, and “ wet periodic infiltration” caused by rain, as well as “continuous” infiltration by under ground water.
- Contribution of the “continuous u. g.” water to total annual water intrusion is significant, is near 100%

following case study proves this claim

CASE STUDY,

A gravity sewer pipe made of 4 ft sections of 10” clay pipe, is in service for less than two years. it is shown in Fig.1, with the following data.

- Pipe length: 6,000 ft.
- Installation slope: 0.0025ft/ft(with manning no of 0.013)
- Annual average under ground water depth: -6 ft.
- Depth of starting manhole : -4 ft.
- Depth of end pipe connected to lift-station :-19 ft.



NEWLY INSTALLED GRAVITY PIPE ARE STRAIGHT AND LEAK FREE

CLAY SEWER PIPE,10" DIA.,6,000.Ft., WITH 5% LEAKY JOINTS

CASE STUDY, CONTINUE,

- Gravity pipe is relatively new and only 5 % of joints in dry & wet soil have opening with width from (1/8" to 0.0") x16" length , that is equal to 1.0 inch^2
- Ft. Lauderdale has annual average of 62.18 inch of rain for last 30 years.
- Lets assume 31 rainy days per year with 2" of rain with duration of 6 hours every time
- 18" diameter manhole's lid has 1/16" crack over 80 % of lid's perimeter, that is equal to 2.8 inch^2

CASE STUDY, CONTINUE, CALCULATION

A- INFLOW:

Rain inflow in man whole 's lid is calculated with

Head pressure "h" of 2" of rain for 6 hours

$V_{(Ft/sec)} = (2g.h)^{½} = 8.025x\ h^{1/2}$ ....(1)

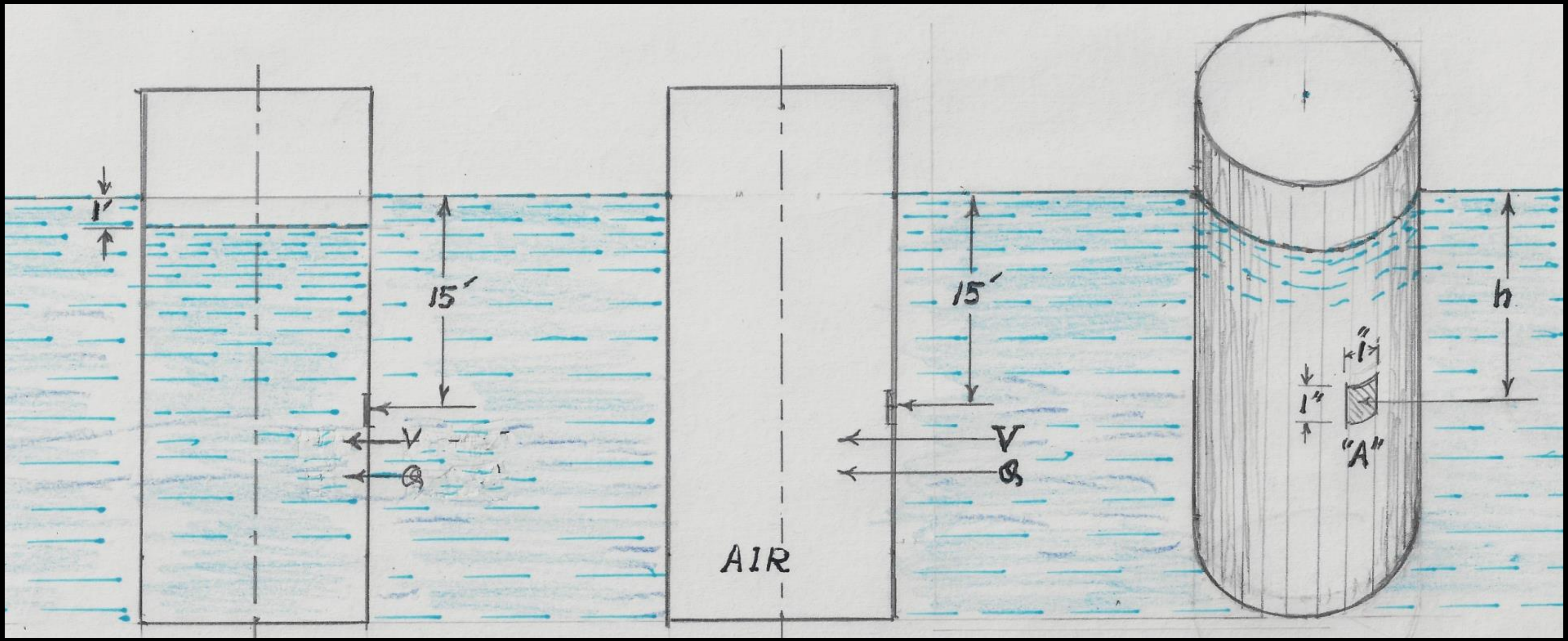
$Q_{(GPM)} = 450\ V_{(Ft/sec)}\ x\ A\ (Ft^2)$ ....(2)

Where:

V : Is water velocity at the lid's crack in (Ft/sec)

Q : Is inflow water through the lid in (GPM)

g : is gravity acceleration, and is 32.2 in (Ft/sec^2)



$V=\sqrt{2gh} = 8.025 \frac{\text{Ft}}{\text{sec}}$

$Q=V*A = 3.34$ *GPM*

$V=\sqrt{2gh} = 31.08 \frac{\text{Ft}}{\text{sec}}$

$Q=V*A = 12.95$ *GPM*

PRESSURE HEAD = " h "

PIPE OPENING = " A "

RELATIONSHIP OF PRESSURE HEAD " h " & VELOCITY " V "

RELATIONSHIP OF FLOW RATE " Q " & VELOCITY "V" & "A"

CASE STUDY,CALCULATION CONT.

G : Gallon, each Ft^3 is equal to 7.49 gallons (1/7.5 Ft^3)

A : Area of crack in (Ft^2)

Substitution of values in equations 1 & 2

V = 8.025x 0.408 = 3.276 Ft/sec in (Ft/sec)

$Q_{(GPM)}$ =450x 3.276 Ft/sec x 2.8 in^2/144 in (GPM)

$Q_{(GPM)}$ = 28.67 GPM

$Q_{(G/YEAR)}$ = 28.67 $_{GPM}$ x6 $_{(Hrs)}$ x60 $_{(min.)}$ x31 $_{(Day/year)}$

$Q_{(G/YEAR)}$ = 319,957 G/YEAR = 0.32 MG/YEAR (MG/year)

CASE STUDY, CALCULATION CONT.

B- DRY SOIL PERIODIC RAIN INTRUSION,

- per fig.1, 800 ft of pipe is in dry soil
- 200 joints are located in dry soil,
- 5 % of joints (10 joints), each one has 1 in^2 opening
- Water pressure head is 2" , (0.167ft)
- Water velocity at joints' crack "V" is V =3.28 ft/sec
- Opening area = 10 joints x 1/ 144 =0.0695 ft^2
- $Q_{(GPM)}$ = A x V = 0.695 x 3.28 x 7.5 x 60 = 102.6 GPM
- $Q_{(G/YEAR)}$ = 102.6 $_{GPM}$ x6 $_{(Hrs)}$ x60 $_{(min.)}$ x31 $_{(Day/year)}$
- $Q_{(MG/YEAR)}$ = 1,145,016 G/YEAR =1.145 MG/YEAR

CASE STUDY, CALCULATION CONT.

C – WET SOIL PERIODIC RAIN INTRUSION,

- 5,200 ft. Of pipe is submerged in U.G. water
- 1,300 joints are under water
- 5 % of joints equal to 65 joints have opening of 1 in^2
- Total area of joint opening = 0.451 ft^2
- Water vilocity at joint = 3.28 ft/sec
- $Q_{(GPM)}$ = A x V = 0.451 x 3.28 x 7.5 x 60 = 665.7 GPM
- $Q_{(G/YEAR)}$ = 665.7 $_{GPM}$ x6 $_{(Hrs\,)}$ x60 $_{(min.)}$ x31 $_{(Day/year)}$
- $Q_{(MG/YEAR)}$ = 7,429,212 G/YEAR = 7.429 MG/YEAR

CASE STUDY,CALCULATION CONT.

D – CONSTANT UNDER GROUND INFILTRATION,

- 5,200 ft. of pipe is submerged in u.g. water
- 1,300 joints are submerged under water
- 5 % of joints equal to 65 joints have opening of 1in2
- Total area of joint opening = 65/144 = 0.451 ft^2
- The joint's pressure head varies from 0.0 to 13 ft.
- Average " V " at joints with "h" = 6.5 ft = 20.46 ft/sec
- $Q_{(GPM)}$ = A x V = 0.451 x 20.46 x 7.5 x 60 = 4,152.4 GPM
- $Q_{(G/YEAR)}$ = 4,152.4 $_{GPM}$ x 24 $_{(Hrs)}$ x60$_{(min.)}$ x365$_{(Day/year)}$
- $Q_{(MG/YEAR)}$ = 2,182,490,928 G/YEAR = 2,182.5 MG/YEAR

INTRUSION CALCULATION SUMMARY

- Inflow of rain water, periodic, only in rainy days

  $Q_{(MG/YEAR)}$ = 0.32 (MG/YEAR)

- Dry soil infiltration, periodic, only in rainy days

  $Q_{(MG/YEAR)}$ = 1.145 (MG/YEAR)

- Wet soil infiltration, periodic, only in rainy days

  $Q_{(MG/YEAR)}$ = 7.429 (MG/YEAR)

- U.G. Water intrusion, constant, invisible, always

  $Q_{(MG/YEAR)}$ = 2,182.5 (MG/YEAR)

- The ratio of periodic intr. To constant is **0.407 %**

CRAVITY PIPE CONDITION,

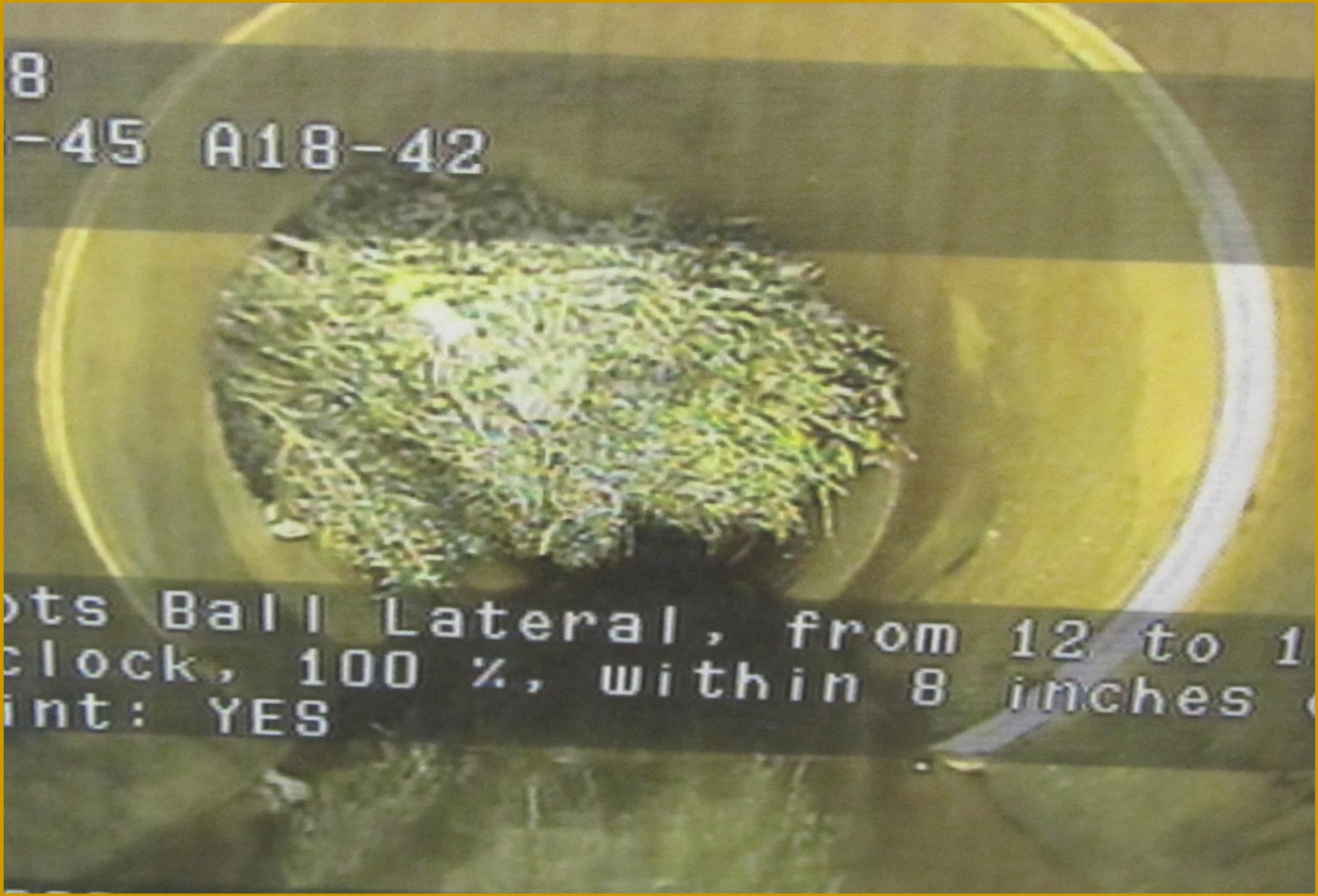
- Gravity pipe at its start point is connected to 4 ft. depth starter man whole, and at the other end it is connected to a intermediate manhole or a lift station
- At the time of installation, the pipe center line is straight with slope of 0.0025 ft./ft.
- The dry soil portion of pipe, does not experience buoyant force, and it is anchored in hard dry soil
- Therefor dry soil pipe remain as original condition.

CAUSES THAT OPEN THE JOINTS:

A- CAUSES IN DRY SOIL,

- The main cause for joint opening in dry soil part of the pipe, is tree roots,(especially rubber tree), that move toward the leaky joints for water and food, and gets in the pipe and open the joints wider.

- Lateral movement of soil, unstable underneath layer could cause lateral or vertical joint opening.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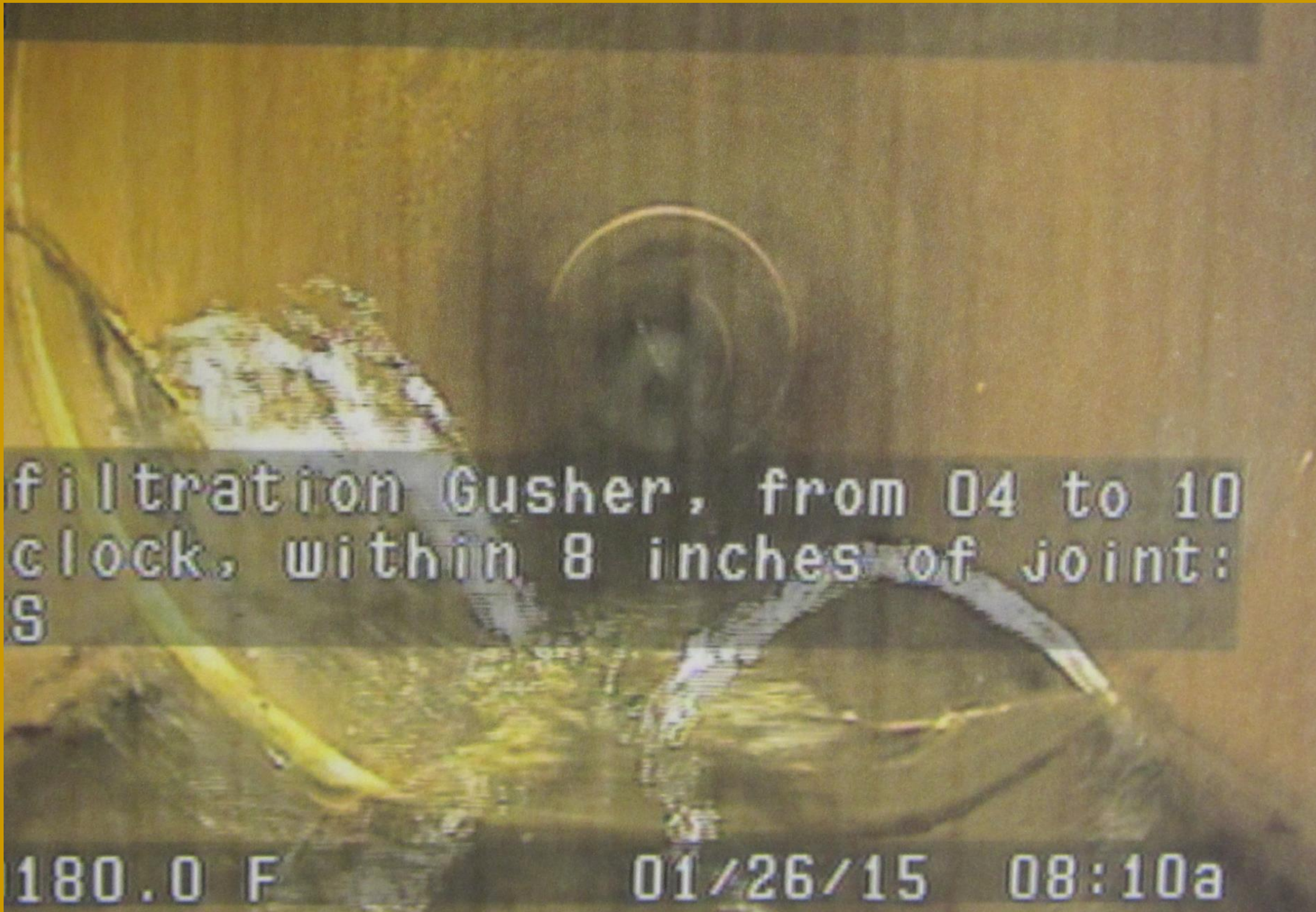
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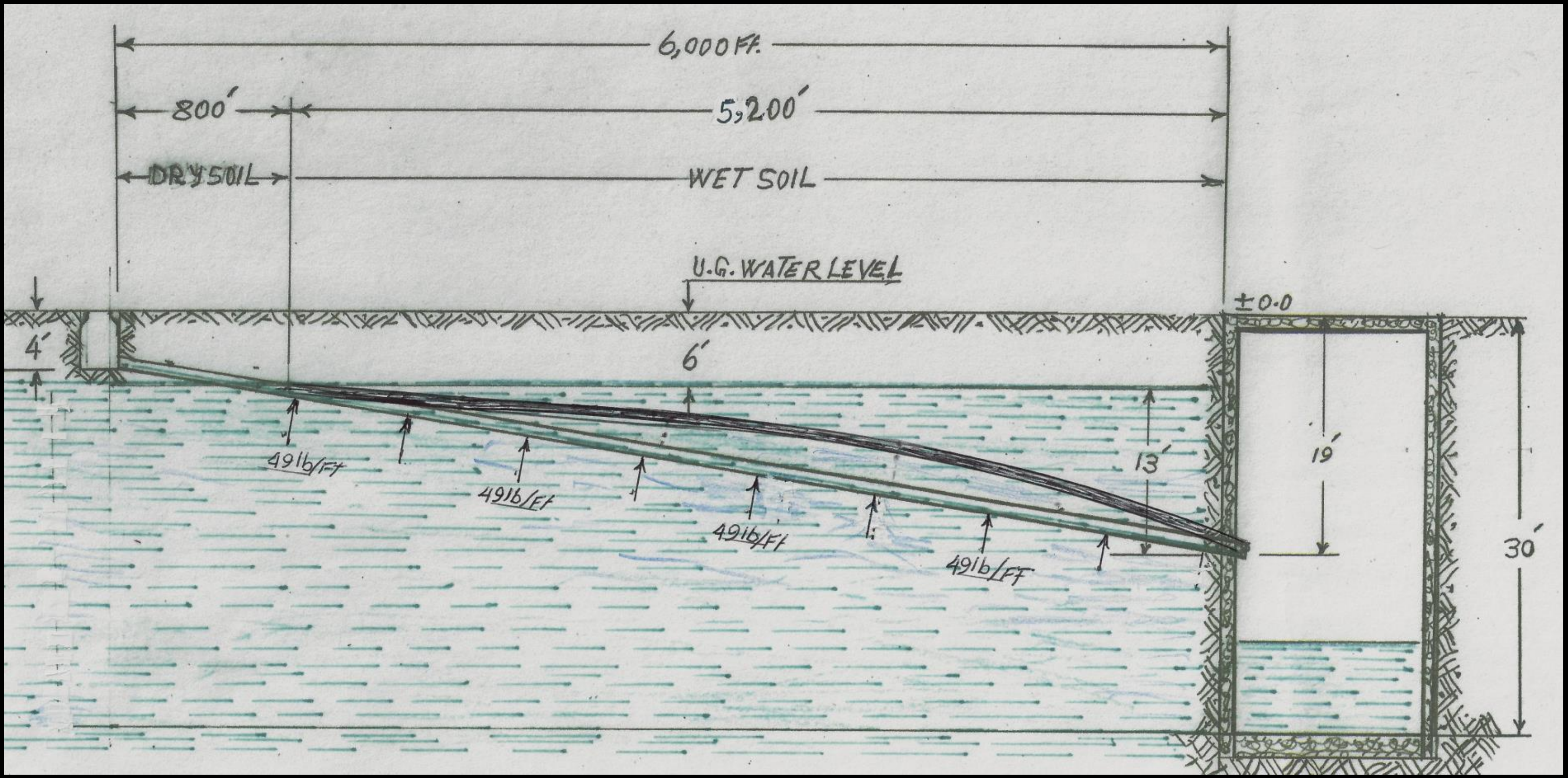
B – JOINT'S OPENING CAUSES IN WET SOIL,

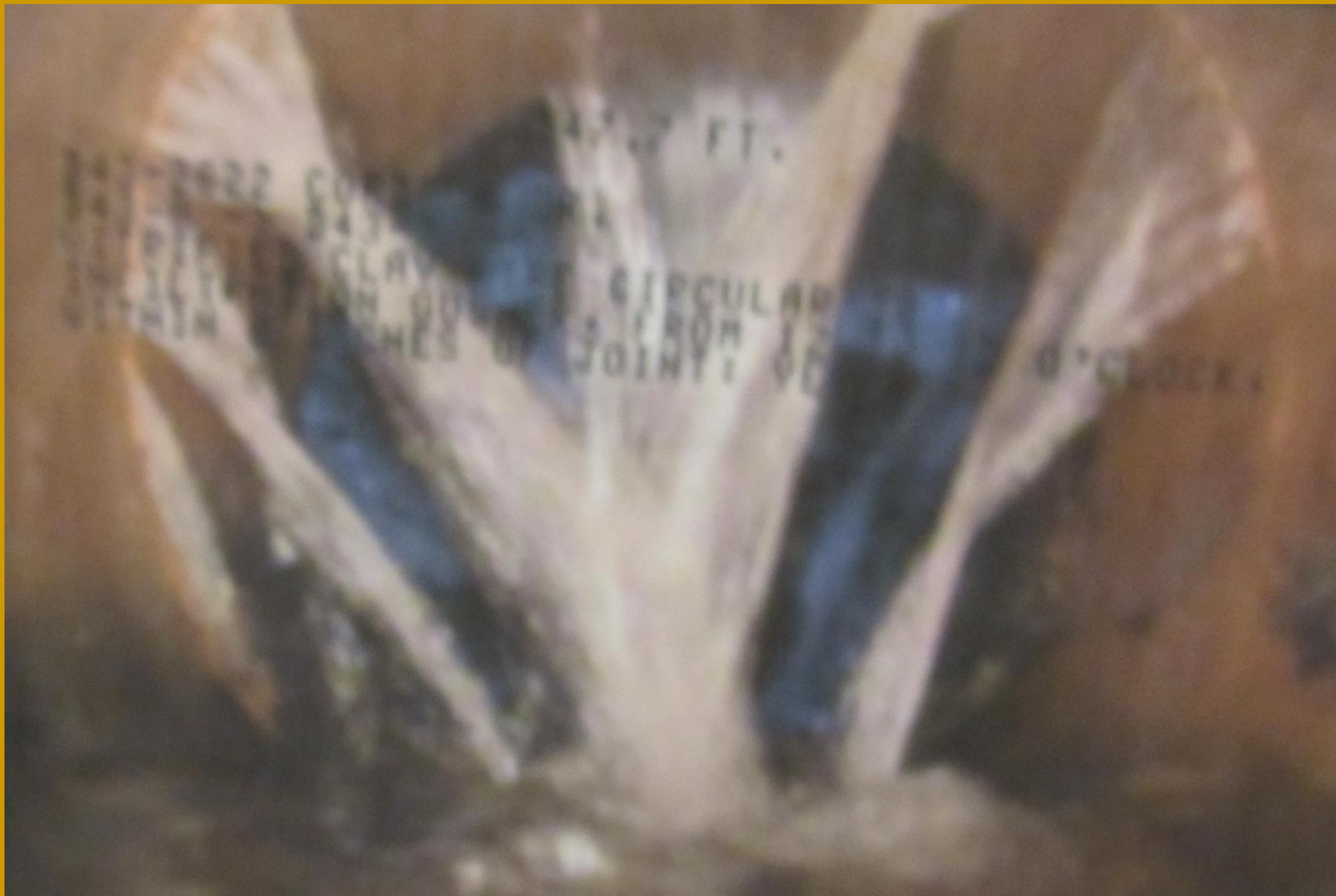
a-ALONG THE PIPE'S LENGTH,

Portion of gravity pipe in the wet soil and submerged location is straight with leak free joints, at the time of installation

- During the service, the joints are subjected to alternative vertical force. This force is the cause of developing open joints by moving the pipe up & down, and loosen all the joints
- This force is always upward, and it bends the pipe upward, its Center line curves up ward and become longer
- This elongation will be compensated by slid out the joints



IN EXISTING LIFT-STATIONS, GRAVITY SEWER PIPE GOES UNDER OSCILLATING BUOYANT FORCE



B – JOINT'S OPENING CAUSES IN WET SOIL,(cont.)

b-AT THE PIPE'S ENDS,

- Gravity sewer pipe at start point is connected to start manhole , this end connection is rigid and all bending moment by up lift force will be absorbed by the part of pipe that is anchored in hard dry soil

- Pipe end at lift-station connection, as result of up lift alternative force imposing to entire submerge portion, vertical force and clockwise moment, rotate and pulls out the pipe end, and create a big opening for u.g. water to rush in to lift-station.

B – JOINT'S OPENING CAUSES IN WET SOIL,(cont.)

c- ALTERNATE FORCE,

A 12" dia. gravity pipe made of 20 ft. sections , cary near zero flow in midnight, and almost full at 6 pm. it is submerged in loos soupy wet soil

- The buoyant up lift force acting on one ft. of pipe is

$$B = 3.1416\ w\ .D^{2}.\ L/4\ (\text{ lb./Ft })$$

B = 3.1416 x62.4x1x1/4 = 49 lb./ Ft. (in midnight)

B = 3.1416 x 0.0 x1x1/4 = 0.0 lb./Ft. (at 6.00 pm)

- The joints under alternate force become loos. this force is continuously upward, cause pipe bends upward

B – JOINT'S OPENING CAUSES IN WET SOIL,(cont.)

d- BUOYANT FORCE OF END CONNECTION TO L.S.

Above 12" dia. gravity pipe , is connected to L.S., at the depth of19 ft. with u.g. water at the depth of 6ft. the water head pressure at the connection is 13 ft.

- Consider only 3 pipe sections, with 2 intermediate joints, each with the rigidity of 67 % in transferring of bending moment of buoyant force to connection.

- B/20"pipe = 49 lb..../Ft . x 20' =980 lb. (in midnight)

  $M_{(at\ connection)}$ = 980 (10'+0.67x30'+ 0.67x0.67x50') lb. x Ft.

  $F_{(uplift\ of\ 3pipes)}$ = 3 x 980 lb. = 2,940 lb. (acts on connection)

B – JOINT'S OPENING CAUSES IN WET SOIL,(cont.)

d– BUOYANT FORCE OF END CONNECTION TO L.S. (cont.)

$F_{(TOTAL)} = F_{(UPLIFT)} + F_{(MOMENT)}$

$M_{(connection)} = 51{,}178$ lb. x Ft.

MOMENT ARM = PIPE Dia./2 = 1 Ft./2 = 0.5 Ft.

$F_{(MOMENT)} = M_{(connection)}$ / 0.5 Ft. = 102,356 lb.

$F_{(TOTAL)} = 2940$ lb. + 102,356 lb. = 105,296 lb.

$A_{(RESISTING\ AREA\ OF\ CONCRETE)}$ = PIPE Dia. $_{(OUT\ SIDE)}$ " x 1" inch ^{2}

$S_{(STRESS)} = 105{,}296$ lb./ 13 in ^{2} = 8,100 PSI

S = 8,100 PSI> 4,000 PSI AND CONCRETE **WILL CRASH**

INFILTRATION IN LIFT-ASTATIONS:

- Existing lift-stations are made from 5 to 8 cylinders with 5' to 6 ft. height, and male & female joints. they are stacked top of each other with sealing compound.
- Wrongfully believed , that the weight of top section is sufficient to make the joints water tight.
- In coastal cities, lift-stations joints are one of the main sources of water infiltration in to lift-stations
- Following calculation determines the magnitude of uplift forces that separate the lift stations' joints.

CALCULATION UPLIFT FORCE IN L.S.

A WET WELL, 12'Dia .MADE OF 6 CYLINDERS WITH 6' HIGHT, AND 12" WALL FROM REINFORCED CONCRETE.

a- WEIGHT OF ONE CYLINDER & TOP SLAB

$$W_{(cylinder)} = 3.14x\ w_c\ x\ D_{(mean)}.t\ x\ H\ (\text{ lb. })$$

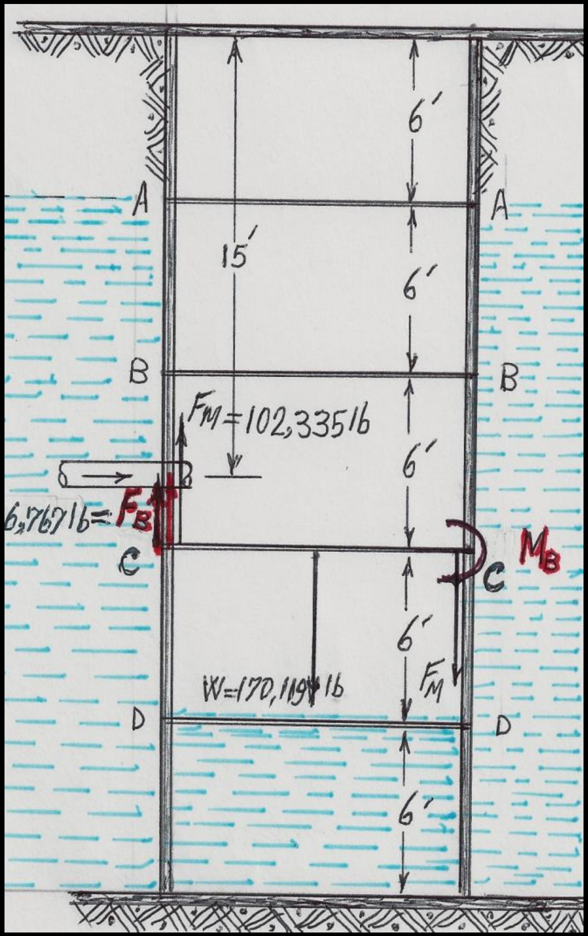
$$W_{(top\ slab)} = 3.14x\ w_c\ x\ D_{(outer)}^2\ x\ h/4\ (\text{ lb. })$$

WHERE,

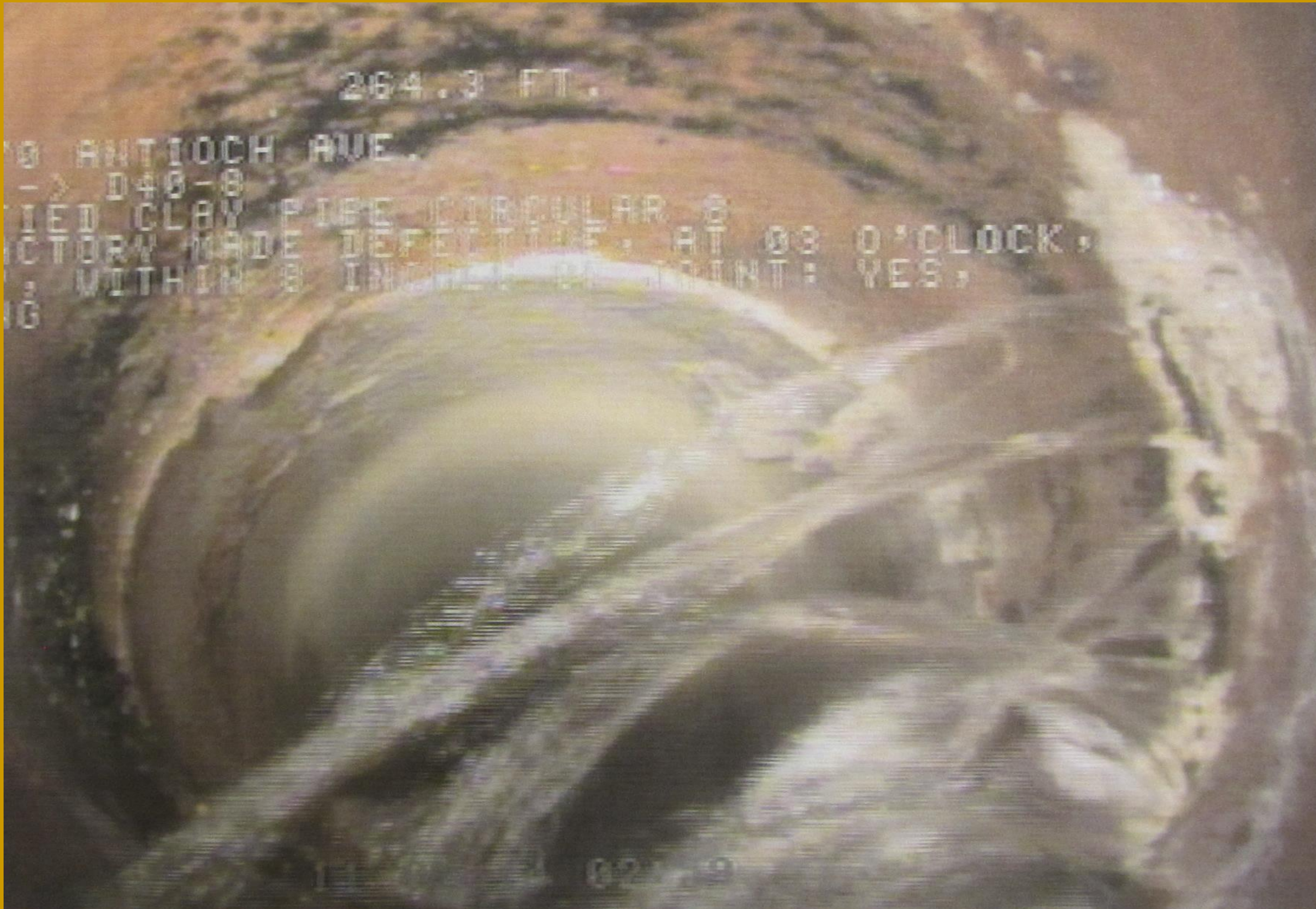
$W_{(cylinder)}$: IS THE WEIGHT OF ONE CYLINDER (lb.)

$D_{(mean)} = D_{(m)} = (D_{(inner)} + D_{(outer)})/2 = 13"$

w : IS SPESIFIC WEIGHT OF CONCRETE =150 (lb./Ft ^{3})



LIFT-STATION,12'x 30'


264.3 FT.
ANTIOCH AVE.
D40-8
IED CLAY PIPE CIRCULAR 8
AT 03 O'CLOCK,
YES,

CALCULATION UPLIFT FORCE IN L.S. (cont.)

H : HIGHT OF CYLINDER (Ft.) = 6 Ft.

h : HIGHT OF TOP SLAB (Ft.) =1 Ft.

t : IS WALL TICKNESS = 12 in

D_i , D_m , D_o : INNER Dia., MEAN Dia., OUTER Dia. = 12 “, 13”, and 14”

b- BUOYNT FORCES ACTTING ON LIFT-STATION’S PIPE CONNECTION

$$B_{\text{(buoyant forces)}} = BF_{\text{(up lift)}} + BF_{\text{(moment)}} \quad \text{(lb.)}$$

WHERE,

B : IS THE TOTAL BUOYANT FORCE ACTTING ON CONNECTION (lb.)

$BF_{\text{(up lift)}}$: IS THE REACTION FORCE OF CONNECTION = 3x 980 =2,740 lb.

$BF_{\text{(moment)}}$: M/Arm = 51,178 lb.... Ft ./ 0.5Ft. =102,356 lb.

$B = BF_{\text{(uplift)}} + BF_{\text{(moment)}} = 2{,}740 + 102{,}356 = 105{,}096$ lb.

CALCULATION UPLIFT FORCE IN L.S. (cont.)

c- THE FORCES ACTING ON JOINT “CC”,WILL BE AS FOLLOWING

1- $W_{(concrete)} = 3 \times W_{(cylinder)} + W_{(top\ slab)}$

$W_{(concrete)} = 3 \times 36{,}757$ lb. $+ 23{,}091$ lb. $= 133{,}362$ lb.

2- $B_{(buoyant)} = 105{,}096$ lb.

d- $M_{(CC)} = B_{(buoyant)} \times 13.5' - W_{(concrete)} \times 7'$ lb. x Ft.

$M_{(CC)} = 105{,}096 \times 13.5' - 133{,}362 \times 7' =$ lb. x Ft.

$M_{(CC)\ (net)} = 1{,}418{,}796 - 933{,}534 = 485{,}262$ lb. x Ft.

e- UPLIFT FORCE ON JOINT “CC” JUST UNDER THE PIPE WILL BE,

$F_{(uplift-net)} = M/Arm = 485{,}262/14' = -34{,}662$ lb.

- JOINT “CC” WILL BE SEPARATED AT MINIMUM FLOW (MIDNIGHT)

INFILTRATION IN MANHOLES

In the resent years gravity sewers are made with PVC pipe sections of 20 ft. with rubber gasket push in joints. They run from manhole to manhole or to lift-stations. At the both end of their connections they will create a upward bending moment, when become submerged. This moment creates an up lift force at the manhole joint below the pipe and just under the pipe.

- Those cracks are temporary, invisible, main source of infiltration, no stain, (be washed continuously by inflow).

RECOMMENDATIONS FOR NEW INSTALLATION

A-GRAVITY SEWER LINE,

a- Instead clay sections of 20' PVC with push in rubber gasket should be used

b- In submerged portion of gravity line, each 20' pipe to be anchored at the center, to privent bending up ward. Anchor should be a helical disk of 8"or10"

c- The existing method of pipe connection to lift station and manhole should be revised as follows

RECOMMENDATIONS FOR NEW INSTALLATION (cont.)

A- GRAVITY SEWER LINE,(cont.)

- Connecting pipe to lift-station must be anchored at 7' from connecting point, with solid anchor tie to lift-station or manhole.
- A conical reinforced connection should connect the pipe to lift-station or manhole as follows,
  - The diameter of cone at connection is (3x pipe's dia.) and other side of cone with (2x pipe's dia.).
  - The cone's length ,should be at least 3'ft.
  - Min. of (12) re-bars #5, 3 ft. length with 4" embedment 6 at top, 6 at bottom, in 120^0 at top & bottom
  - Min .4,000 psi concrete should be used

RECOMMENDATIONS FOR NEW INSTALLATION (cont.)

B-LIFT-STATIONS & MANHOLES

a- Water intrusion to wet well completely eliminated. with pre fab. green wet well by global green lift.

all sections of green wet well have flange and will stacked on top of each other . Their flanges connect together, using gasket and bolts & nuts.

b- In traditional concrete wet well ,the joints under the pipe connection, should be reinforced vertically with stainless-steel 316 plate and Topcon Fasteners this reinforcement will absorb the uplift force of pipe connection moment.

EXISTING SEWER SYSTEM,

" I& I " in both rain and u.g. continuous infiltration, "Q" eq.(1) or (2), is a function of joint opening area "A" and water velocity "V" at the joint, or water pressure head " h ".

$$Q = A \times V \text{ .... } (1)$$

$$Q = 8.025\ A \times h^{1/2} \text{ .... } (2)$$

By elimination of "A" or " h " or both, "I &I" will be eliminated

EXISTING SEWER SYSTEM, (cont.)

A-ELEMINATION OF JOINT OPENINGS "A",

At present time the industries' focus is, to eliminate joints opening by the following methods.

a- In clay gravity pipe, continuous inner lining with PVC liquid and harden it with steam.

b- Find open joint with camera. seal it locally from inside, by blocking both side of the joint and inject sealant with pressure.

c- polyurethane injection from out side of the opening, most commonly used is in manholes and lift-stations

- ALL OF THE ABOVE ARE VERY COSTLY

EXISTING SEWER SYSTEM, (cont.)

B-REDUCTION OR ELEMINATION OF " h "

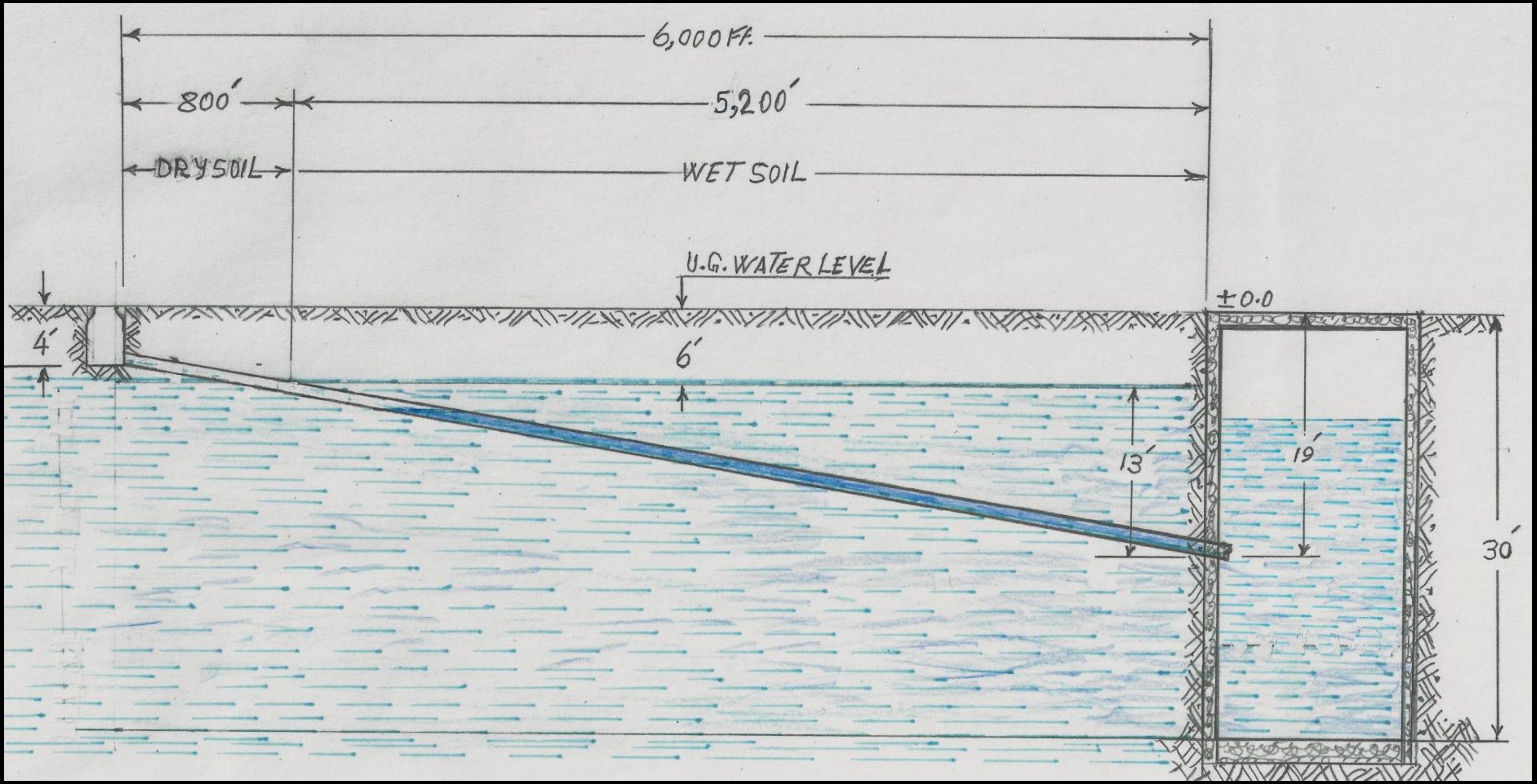
- Continuous "I & I" is under ground water intrusion that is responsible for 99.6 % of total "I & I"
- The force behind this infiltration is U.G. water head "h", that varies along the gravity sewer line.
- Per eq.(2), when "h" reduces and approaches to zero, "Q" also will reduces and approaches to zero.
- Reduction of "h" is a new concept . It is not in the interest of industry, because it is not profitable to them. Therefore their experts will criticize it.

EXISTING SEWER SYSTEM, (cont.)

SIMPLE SOLUTION FOR ELEMINATION OF " h "

WITH NO CAPITAL COST,

- "h" varies from 0.0 at starting manhole to 20 ft. in lift station connection.
- "h" at one joint varies when under ground water oscillates seasonally.
- Green lift-station design with its special control system is able to reduce "h" at any desired amount from 20 ft. to 1ft.
- the smart green lift-stations by Global Green Lifts are capable of following the seasonal variation of u.g. water level and maintain the "h" value as low as 8" inches at all the time.

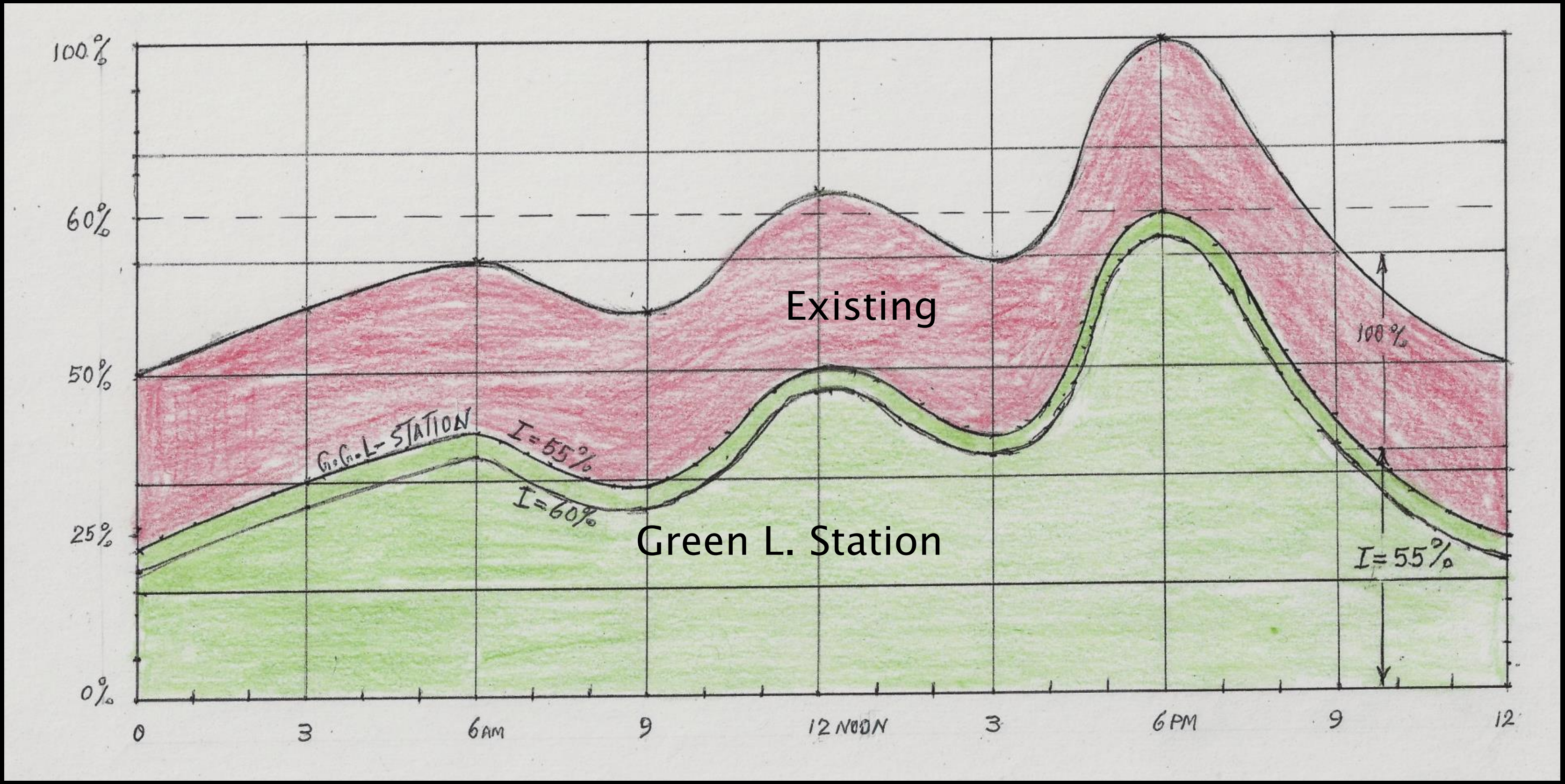


GREEN LIFT-STATION PROTECTS GRAVITY SEWER PIPE FROM BUOYANT FORCE

REDUCTION OF (I & i) WITH OUT CAPITAL & RUNNING COST BY GLOBAL GREEN LIFT-STATIONS										
ITEMS	GROUND DEPTH TO		EFFECTIVE ORIGINAL WATER HEAD Ft.	PRESSURE REDUC. by GLOB. G.L. STATION Ft.	EFFECTIVE PRESSURE USING G.G.L.STA. Ft.	AVE.PRESSURE ALONG G.PIPE USING G.G.L.STATION Ft.	AVE.VILOCITY ALONG PIPE v=$\sqrt{2gh}$ v= 8.025$\sqrt{h}$ Ft./SEC.	REDUCTION of Q (I & I) $\frac{Q(I\,\&\,i)G.G.}{Q(original)}$ %	PLANT RESEVE CAPACITY by G.G.L.STA. %	PLANT OPERAT. FLOW by g.g.ls %
	PIPE CONNEC. Ft.	U. G. WATER Ft.								
1	19	6	13	0	14	7	20.46	100%	0.00%	100%
2	19	6	13	2	11	5.5	18.82	92%	4%	96%
3	19	6	13	4	9	4.5	17.02	83.20%	8.40%	91.60%
4	19	6	13	6	7	3.5	15.01	73.40%	13.30%	86.70%
5	19	6	13	8	5	2.5	12.67	61.92%	19.04%	80.96%
6	19	6	13	10	3	1.5	9.83	48.04%	28%	72%
	REDUCTION OF (I & I)WITH OUT CAPITAL& RUNNING COST WITH SMART G. W. LEVEL SENSING GREEN LIFT-STATIONS									
7	19	6	13	11	2	1	8.O2	39.22%	30.39%	69.61%
8	19	6	13	12	1	0.5	5.67	27.73%	36.14%	63.86%
9	19	6	13	12.34	0.66	0.33	4.61	22.53%	38.74%	61.26%
	1- AT THE POINT OF CONNECTION TO L.STATION h= 13 Ft. AND VELOCITY V= 28.93 Ft./SEC.									
	2 - IN SIDE PRESSURE IS 12.34Ft. AND V= 28.19Ft./SEC.									
	3-THERE IS INFLOW FROM INSIDE OF PIPE TO OUT SIDE WITH V= 0.75 Ft./sec.									

APPLICATION OF GREEN LIFT-STATIONS TO CONTROL " I & i " AND INCREASE PLANT CAPACITY

REDUCTION OF " I&i " DOWN FROM 100% TO 23% , AND PLANT'S RESERVE CAPA. UP FROM 0% TO 40%



PLANT RESERVE CAPACITY INCREASES FROM 0% to 40% BY GREEN L.STATION

GREEN L.STATION WILL SAVE RUNNING COST AND ENERGY COST BY 40%

NEAR TOTAL ELIMINATION OF “I&I” WITH LIMITED FUND,

Most of the cities have very limited fund, or fund is spread over period of several years. It is essential in fighting with “ I&I ”, take a route with the minimum cost and maximum benefit.
The following are steps toward to this effort.

1-All existing pump-stations should be ranked per following equation.

$$R = 100 * \frac{h_h}{H} * \frac{(5Lc + Lp)}{L_t} * \frac{a}{30}$$

Where:

R : is the ranking number
h_h: is the highest U.G. Water table among the city’s sewer basins.
H : is the U.G. Water table of individual sewer basin
a : is the service age of gravity sewer, and 30 year is the life span of the pipe

NEAR TOTAL ELIMINATION OF "I&I" WITH LIMITED FUND,(cont.)

L_c: is the total length of clay gravity sewer pipe
L_p: is the total length of PVC and Ductile Iron sewer pipe
L_t: is the total length of lift-station gravity sewer pipe

2- Select the twenty top lift-stations from above ranking.
3- Apply clamp ultra sound flow meter for a period that include at least four rainy days, and collect data for rainy and sunny days.
4- Average flow data of rainy and sunny days for 20 lift-stations, should be calculated. The ratio of rainy day flow to sunny day flow should be obtained.
5- Appling above ratios, new ranking for 20 lift-stations in order of descending should be arranged.
6- With consideration of available fund a number of lift-stations, in order of ranking, should be selected for "I&I" elimination.

DESIGN PROCESS TO ELIMINATE "I&I" WITH LIMITED FUND,

The following processes in order of priority should be followed

1- All selected lift-stations, should be converted to Green lift-stations technology. This will reduce the total "I&I" from 100% to 30% without any capital spending for "I&I" projects.

2- For eliminating of remaining 30%, stablish a pilot project for top five lift-stations and implement the following steps, while monitoring the Lift-stations' discharge flow.

   a- Check the gravity pipe connections to lift-stations and manholes. The lift-station's male& female connection joint under inflow pipe should be reinforced with stain less steel strap & S.L.S.Tapcon screws, when connection is not leaking.

DESIGN PROCESS TO ELIMINATE “I&I” WITH LIMITED FUND,(cont.)

b- Lining the old, submerged gravity clay pipe start from lift-station to under ground water level.

c- With camera check the connection of lateral to gravity main and repair the broken connections locally.

d- With camera inspect the remaining clay pipe, and repair it , if it is needed.

e- Seal the manholes’ lids with rubber gasket.

f- with continuous monitoring the discharge flow, the effectiveness of each step can be measured.

g- most likely beyond these stages, a minor improvement could achieve with a major expense.

This pilot project, provide us a tested guideline for rest of Stations

CITY OF FORT LAUDERDALE:

The Running cost of City Sewer System is the topic of this study.

1-Population: 172,389 people and annual growth rate of 1.25%.

2-Area: The Total area is 38.6 square miles,(99.9 sq. Km.), with;

- a- Dry land area: 34.7 square miles,(90 sq. km).
- b- Water area: 3.8 square miles,(9.9 sq. km).

3- Elevation: 9 Ft.(2.75 m) from Sea.

4- Rain Fall: Average of 62.18 inches annually in last 30 years.

5- The highest single day rain fall is 12.25 inches in Oct.1942.

6- City Sewer System Annual Running cost of "Pump in" and "pump out".

A- Lift-Stations:

a- The Total city L.S. with two and three pumps is	216	L.S.
b- The Total City Horse Power installed in Lift-Stations:	9,470	H p

B- GTL Deep Well injection: with total of four pumps.

a- Two pumps, 880 Kw,(1180 H p), each.	2,360	H p
b- Two pumps, 1234 Kw,(1655 H p),each.	3,310	H p

ANNUAL SEWER SYSTEM RUNNING MATERIAL, & ENERGY COST
EXISTING (Sept 2014 to Sept 2015)

1-chlorine	$ 70,584
2-hydrogen Peroxide	$345,612
3-polymehrs	$284,227
4-liquied Oxygen	$ 87,748
5-water/Sew/Storm	$354,735
6- Running Energy used	
a-pumping In, Lift-stations	
10,382,792kwhx 10cents	$1,038,279
b-pumping Out, Power Deep Well	
20,313,670kwhx 7.26 Cents	$1,474,772
c-inside GTL, power	
6,879,053kwhx7.26 Cents	$ 499,419

- Total Running Cost $4,155,376 (100%)

(I & i) RELATION with RUNNING MATERIAL, & ENERGY COST

City of Ft. Lauderdale is a coastal City with serious (I & i) problem.
The City's amount of (I & i) is not known. The City personals believe the (I & i), will be between 55% to 60% of inflow entering to GTL.
In this study a conservative number of 55% has been used.
From 100 Ga of inflow, 45 Ga is real sewer and 55 Ga is clean U. G. water In form of (I & i).

IF, we reduce (I & i) from existing of (100%) to (25%), then:

$\text{Inflow}_{\text{(new)}} = 45\text{ Ga}_{\text{(real sewer)}} + 55\text{ Ga}_{\text{(I \&i)}} \times 25\% = 58.75\text{ Ga}$

The resulting saving on running cost will be;

$\text{SAVING}_{\text{(I \& i) reduction}} = 100\% - 58.75\% = 41.25\%$

$\text{SAVING}_{\text{(I \& I from100\% to 25\%)}} = 41.25\% \times 4{,}155{,}576 = \$\ 1{,}714{,}092.\text{-}$

HOW (I & i) CAN BE REDUCED from 100% to 25% ?

One of the following methods could be used.

1- If the gravity sewer pipe is clay, too old, too long, and too deep it is feasible to be replaced by a new Lift-Station with a shallow force main.

2- LINING:

To day common practice, is inside lining with PVC.
To achieve 75% reduction, about 75% of gravity sewer pipe should be lined.

- City of Key west, with 25,000 population spent $ 65.million in its (I & i) project. Its capital index is $ 2,600.- per person.
- There is close similarity between key west and Ft. Lauderdale and Key west index can be used for (I & I) budget estimation for FT. Lauderdale, and estimated budget will be;
- Capital cost= 172,389 x$ 2,600= **$ 448.2 millions**

HOW (I & i) CAN BE REDUCED from 100% to 25% ? Conti.

- If the reduction is 75%, then the City's Saving will be $1,714,092.
  Years of Capital Return= $448.2/1.714= **261.5 years**

- Lining has limited life,
  Per Manufacturer the lining material last 50 years in testing lab, but working conditions not lab condition. In sewer gravity pipe lining is expose to harsh chemical, corrosive and erosive condition, and mechanical stresses. Lining loses its elasticity, become brittle and fail. It might last 20 to 25 years.

- Economically, it is not feasible:
  In 25 years, the total compounded capital return is ;
  29.135 x $1,714,092 = $49.940 million
  The Capital Loss would be $448.2 – $49.940 = **$398.26 million**
  The Annual Capital Loss would be $ 398.26/ 25 years = **15.93 million/year.**
- lining can not be qualified for Federal Grant.

HOW (I & i) CAN BE REDUCED from 100% to 25% ? Conti.

3-Applying Green Lift Technology :

- No Capital Cost:
  By conversion of existing Lift-stations to Green lift- stations, the (I & i) reduction of 75% will be achieved with out any capital cost for(I & i).
- Annual saving:
  Due to (I & i) reduction of 75%, there is a Saving of;
  4,155,376. x 41.25% =**$ 1,714,092.**
  with Smart Green-Lift-Station, even further saving is possible.
- No life limitation:
  The life of (I & i) saving is unlimited.
- Green-Lift -Stations Save Energy, and are qualified for Federal Grant.
- GTL Capacity Expansion:
  The GTL treatment capacity, will be expanded from 100% to 141.25%. No plant expansion is required for another 30 years.
- Environmentally is friendly, less CO_2 be released to atmosphere.

TOTAL ANNUAL ENERGY SAVING
by GREEN-LITF-TECHNOLOGY

Applying Green-Lift-Technology to "pumping process", will results In the Following Energy Savings:

a- (I & i) REDUCTION: Energy saving by 75% (I & i) reduction is;

- Saving$_{(I\ \&\ i)}$ = \$3,012,470. x41.25% = \$1,242,644.

b- LIFT-STATIONS:

Conversion of existing L.S. to Green lift-stations will result in energy saving of 40% on reduced inflow of 58.75% of original flow.

- Saving$_{(L.S.)}$=1,038,279 kwh x 58.75% x 40% x10 c/kwh = \$ 243,996.

c- GTL DEEP WELL:

By applying the Green-Lift Technology and constant speed pumps, will be a saving of 70% on reduced inflow of58.75% of original flow.

- Saving$_{(GTL)}$=20,313,670 kwh x 58.75% x70% x7.26 c/kwh = \$606,500.

Total Energy Saving by "Green lift Tech.". \$ 2,093,140. (69.48%)

ANNUAL SEWER SYSTEM, MAINTENANCE SAVING by GREEN-LITF TECHNOLOGY

By conversion of existing Lift-Stations to Green-Lift-Stations, and by applying the Green-lift Technology in " pumping process ", the pump's life span will increases by 400%.
Further more, costly repair and every 6 to 8 years, replacement of VFDs Totally will be eliminated.

The exact amount of annual maintenance for lift-stations is not known.
The average existing maintenance cost, for lift-stations and GTL is;

a- Lift- Stations: $2,200,828.
b- Deep well injection: $1,384,692.

a- Lift-Stations:

Saving by Green-Lift is averaged to 65%.
Annual Saving in L.S. = 65% x 2,200,828. $1,430,538.

b- Deep Well injection:

Saving by Green-lift Technology estimated to75%.
Annual Saving in GTL deep well =75% x$1,384,692. $1,038,519.

Total Annual Maintenance Saving $2,469,057.

CONVERSION COST of EXISTING L.STATIONS to GREEN-L. STATIONS

To convert the existing Lift-Stations to Green Lift-Stations the following modification should be done.

1- Integration of Green-lift control with existing control.	$ 15,000.
2- Remove and replace the top slab with Green lift cover.	$ 10,000.
3- Remove of pumps and replace them with three smaller, pumps with total Hp. Installed 60 to 70% of existing, and piping arrangement.	$ 60,000.
4- Data gathering, and engineering.	$ 15,000.
5- Over head and profit.	$ 20,000.

Average Total Conversion Cost/each $120.000.

6- City's Total Conversion Cost= 216 x $ 120,000.= $ 25,920,000.

7- Annual Saving by Green lift technology is; $5,033,645.

8- The Annual Rate of Return is $5.033/25.92= **19.42%**

SUSTAINABILITY & ENVIRONMENTAL IMPACT

Sewer System Total Energy Used in 2015 is: 37,575,515 Kwh

Annual energy Saving in Sewer System, by
" Green Lift Technology".

1- Saving by (I & i) reduction, (41.25%) , is:
37,575,515Kwh x41.25% = 15,499,900 Kwh

2- Saving of 40% in L. Stations with
constant speed pumps is:
10,382,792 Kwh x58.75%x 40% = 2,439,956 Kwh

3- Saving of 70% in Deep Well with
elimination of VFDs.
20,313,670 Kwh x58.75%x 70% = 8,353,997 Kwh

Total Annual Energy Saving: 26,293,853 Kwh

To generate,1Kwh electricity, 2.18 lb. (near 1Kg) CO_2
along with other Toxic gasses, will be released into atmosphere.

- CO_2 (not released)=2.18 lbx26,293,853 Kwh=**28,660 tons/year**

SEWER SYSTEM ANNUAL RUNING COST OF EXISTING, and SAVING BY APPLYING GREEN- LIFT TECHNOLOGY								
	PERIODS	1-YEAR	5 YEAR PERIOD		10 YEAR PERIOD		25 YEAR PERIOD	
ITEMS	DESCRIPTION	YEAR 2015	2015 to 2020		2015 to 2025		2015 to 2040	
		VALUES YEAR 2015 $ C1	Accumulated 5 years with 0% Inflation $ 5.1266 C1	Accumulated 5 years with 2% Inflation $ 5.3384 C1	Accumulated 10 years with 0% Inflation $ 10.582 C1	Accumulated 10 years with 2% Inflation $ 11.610 C1	Accumulated 25 years with 0% Inflation $ 29.1354 C1	Accumulated 25 years with 2% Inflation $ 37.805 C1
	Runing Cost:							
1	Runing Energy &Material	4,155,376.-	21,302,951.-					
2	Runing Lift-station Maint.	2,200,828.-	11,282,765.-					
3	Runing GTL D.W.Maint.	1,384,692.-	7,098,762.-					
	Total Annual Runung Cost	**7,740,896.-**	**39,684,477.-**	**41,323,999.-**	**81,914,161.-**	**89,871,803.-**	**225,531,005.-**	**292,605,869.-**
	Saving by (I&I)Reduction							
A	**From 100% to 25%**	1,714,092.-	8,787,464.-	9,150,509.-	18,138,522.-	19,900,608.-	49,940,070.-	64,801,248.-
	Saving By G.L. Technology							
B1	40% energy saving in lift-							
	Stations by Green-Lift	243,996.-	1,250,870.-					
B2	70% energy saving In GTL	606,500.-	3,109,283.-					
B	**Sub Total Eenergy Saving**	850,496.-	4,360,153.-	4,540,288.-	8,999 949.-	9,874,259.-	24,779,201.-	32,148,749.-
	Maintenance Saving by **Green Lift-Technology**							
C1	65% in Lift-station Maint.	1,430,538.-	7,333,796.-					
C2	75% in Deep well injecti.	1,038,519.-	5,324,072.-					
C	**Sub Total Maint.Saving**	2,469,057.-	12,657,868.-	13,180,814.-	26,127,561.-	28,665,752.-	71,935,976.-	93,330,355.-
TS	**TOTAL Annual Saving by Green Lift Technology**	**5,033,645.-**	**25,805,484.-**	**26,871,610.-**	**53,266,031.-**	**58,440,618.-**	**146,665,247.-**	**190,271,781.-**

Conclusion:

1- Elimination of (I & I) in coastal cities is essential and MUST be done. Several methods have been used, the most common practice is inside lining of gravity pipes, but it is not the best, and other methods may be feasible.

2- For very old large clay pipe, (specially when it is submerged and long),it is chipper to be replaced with new small lift station and shallow force main.

3- Pipe Lining:

- a- It is costly,
- b- Its effective life is limited due to harsh working condition of mechanical and chemical stresses. Most of the time it does not return its initial capital cost.
- c- It can not be qualified for Federal Grant.
- d- It has negative return, actually Annual capital loss of 15.93 million.

4- (I & i) elimination by Green-Lift Station:

- a- Very low initial capital cost.
- b- No life limitation.
- c- It will be in top list of Federal Grant projects.
- d- Its Annual Energy saving is over 69.48% of existing Energy used.
- e- Environmentally is friendly, less energy associate with less CO_2.
- f- It preserve the sewer collecting system from further deterioration.

Q questions

&

A answers