DIRECTIONAL DRILLING
BEST PRACTICES

Planning & Construction Considerations

WOODARD
&CURRAN

COMMITMENT & INTEGRITY DRIVE RESULTS

Today’s presenters will be:

Dennis M. Walsh, PE

Sr. Project Manager

Woodard & Curran

Daniel D’Eletto, PE

Manager, Project Engineering & Design

National Grid, USA

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&CURRAN

There are Many Tools

IN THE TRENCHLESS TOOLBOX

- Auger Boring/Jack and Bore
- Pipe Ramming
- Boring Tools (Impact Moles)
- Microtunneling
- Pilot Tube Microtunneling
- Pipe Bursting
- Cured In Place Pipe (CIPP)
- Pipe Splitting
- Horizontal Directional Drilling or HDD

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Trenchless Technology –

THE EARLY DAYS

- Trenchless technology has been around for many decades
- Auger or Jack and Bore in use for 40-50 years
- Impact moles were popular for street crossings and to go under rock gardens
- Directional Drilling, or HDD started to gain popularity in late 80’s
- NASTT formed in 1990
- Utilities started using HDD in the early 90’s

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Over the Last 25 Years

TRENCHLESS TECHNOLOGY HAS EVOLVED

- Cultural transformation
- Learning new ways
- Sharing the risks
- Using the right tool from the tool box
- Equipment got bigger and more powerful
- Drilling accuracy got much better
- Drills got longer with Intersect Drilling
- But remember, it is still an art and a science!

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Of course, it is Not as Easy

AS IT LOOKS

The Benefits of Trenchless Technology

ARE MANY

- Avoids disturbance of roads and environmentally sensitive areas
- Eliminates the non value added activities of pipe construction
- Saves money in paving costs
- Minimizes impact on Quality of Life for community (no traffic detours, lane closures, etc.)
- Of course, not everyone sees the benefits

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Proper Planning Is a Must

- Review job requirements
- Walk job and see the job layout up close
- Google maps can be a great start
- What are the constraints?
- What is the length of project?
- What construction areas do you need and what is available?
- What is the required pipe size and material?
- Geotech conditions? Soil types? Desktop review.

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Carefully Review the Route

AND THE OBSTACLES TO BE CIRCUMVENTED

- Environmentally Sensitive Areas
- Highways
- Rivers
- Railroads
- One route may be better than all the others
- Other obstructions
  (foundations, piles, deep sewers)

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Review Agency Requirements

AND SUBMITTING PERMITTING APPLICATIONS

- Follow appropriate agency rules and regulations
- In drilling under railroads, need to follow requirements such as Conrail CE-8
- It’s an educational effort along the way

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Engineering Design Considerations

- Survey the site or use GIS
- Do a preliminary piping layout
  - Entry angle of 8 to 16 degrees
  - Exit angle of 5 to 10 degrees
- Conduct Geotechnical investigation
- Include soils analysis and lab tests on rock
- Room for drill rigs and pipe laydown areas
- Pre Final Design
- Determine Pipe Stresses
- Final layout and design

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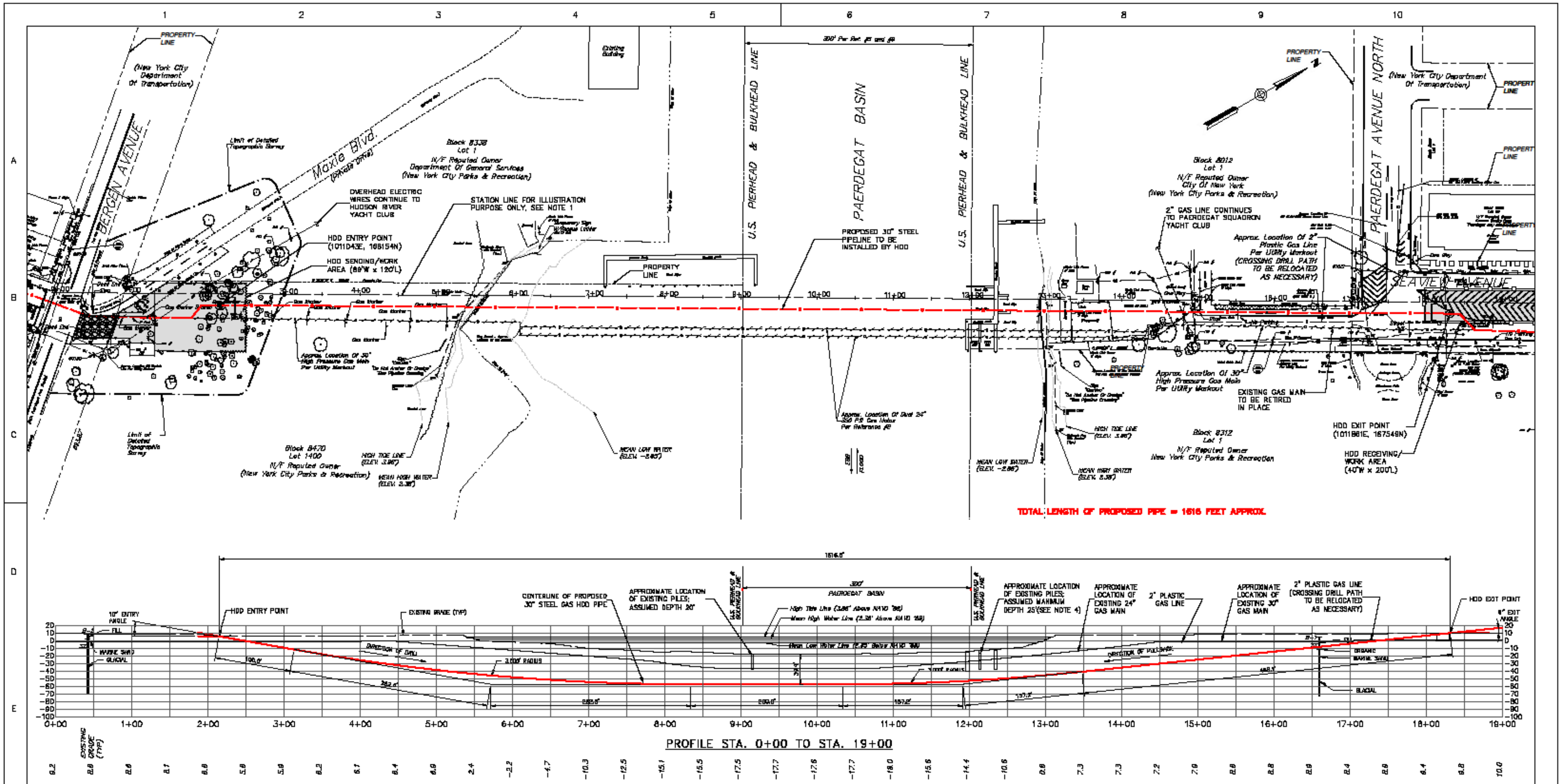
Additional Design Considerations are

- Layout Area for Pullback Pipe
- Can require up to 1 Acre of Drill Rig Lay down Area
  - Small Rig <40,000 lbs. = 20’ x 80’
  - Medium Rig 40,000 -100,000 lbs. = 100’ x 150’
  - Large Rig > 100,000 lbs. = 150’ x 250’
- Frac Tanks, Mud Tanks, Drill Pipe, Power Unit, Control Cab

WOODARD &CURRAN



PROFILE STA. 0+00 TO STA. 19+00

CLARIFICATION NOTE:
PROFILE SHOWN IS AT THE PROPOSED GAS LINE. THE STATION LINE IS MOVED AND IS SHOWN FOR ILLUSTRATION ONLY.

REFERENCE:
EXISTING CONDITIONS INFORMATION DEPICTED ON THIS PLAN WAS OBTAINED FROM PLAN ENTITLED: "PARTIAL BOUNDARY & TOPOGRAPHIC SURVEY" NATIONAL GRID PAERDEGAT BASIN GAS PIPELINE CROSSING, BOROUGH OF BROOKLYN, KINGS COUNTRY, NEW YORK, PREPARED BY CHERRY WEBER VAN CLEEF ENGINEERING ASSOCIATES, P.C. DATED: 4-4-2011.

NOTES:
1. REFER TO SURVEY DRAWINGS ISSUED BY CHERRY WEBER VAN CLEEF ASSOCIATES DATED 4-4-2011 FOR STATION LINE.
2. EDGE OF WATER VARIES BASED ON TIDAL CONDITIONS.
3. PAERDEGAT BASIN IS NOT A FEDERAL CHANNEL OR STATE WATERWAY AT TIME OF DESIGN.
4. ON JULY 6, 2011 W&C MET WITH REPRESENTATIVES OF MIDGET SQUADRON YACHT CLUB AND DETERMINED THAT THE DEPTH OF THE PILES RANGED FROM 15 TO 25 FEET DEEP.

90' 0 90'
BAR SCALE
1" = 90'
CHECK GRAPHIC SCALE BEFORE USING

DENNIS M. WALSH
NYS – 058091-1

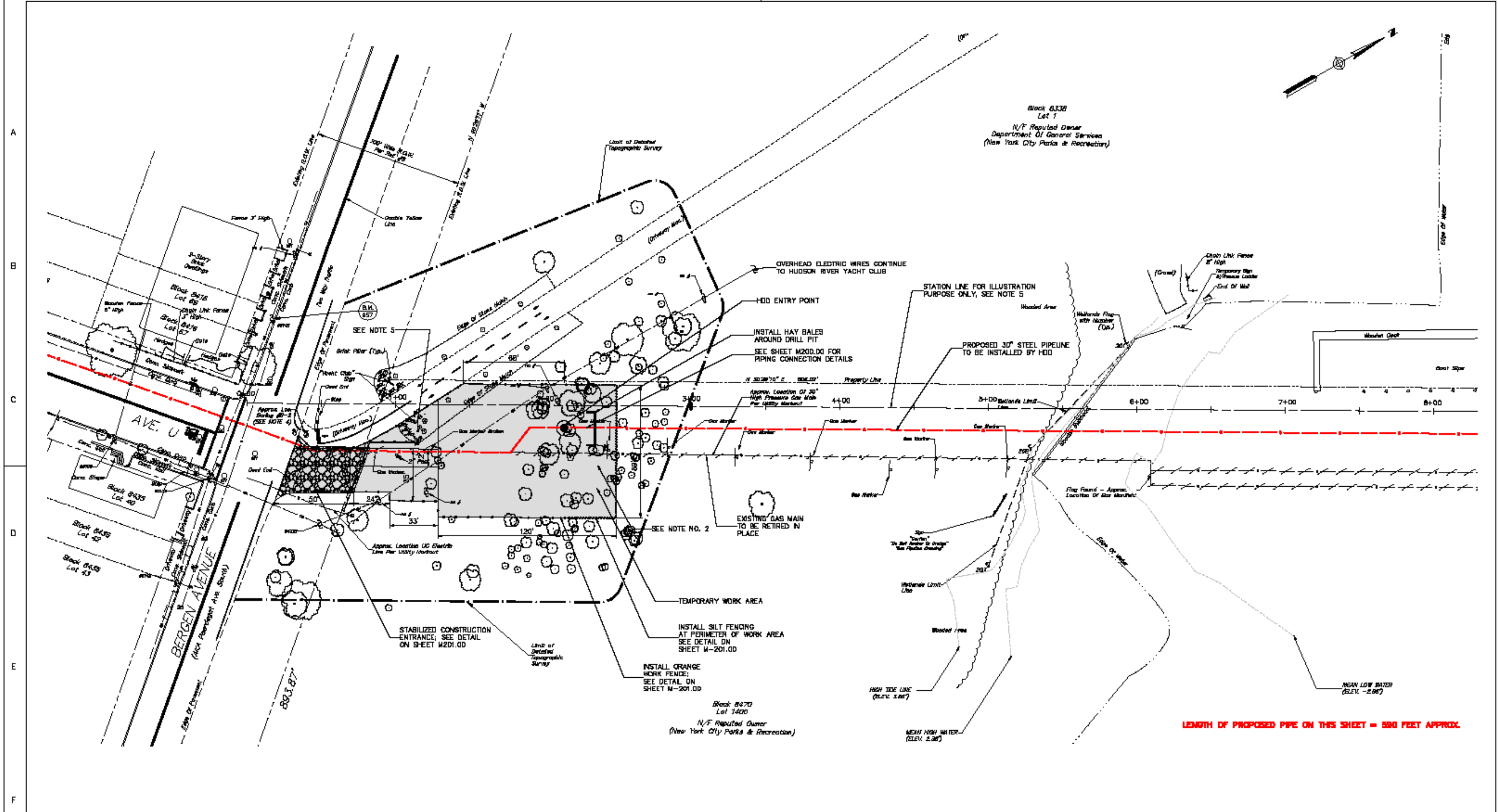
NO.	DATE		DESCRIPTION				
3	2/08/12		REMOVED VAULT AT HDD EXIT POINT	M	F	R	F
2	1/18/12		ADDED TOTAL LENGTH OF PROPOSED PIPE	M	F	R	F
1	11/11/11		EXTENDED HDD ENTRY POINT 40' REST, INCREASED TEMPORARY WORK AREA, REMOVED VAULT AND REMOVED PERMANENT WORK AREA	D	F	R	F

PAERDEGAT BASIN CROSSING, GAS PIPELINE PROJECT
KINGS COUNTY, BROOKLYN, NY

HDD DESIGN PLAN & PROFILE OVERVIEW

NATIONAL GRID

DATE: 9/21/11
SCALE: 1"=90'
223771-SITE.dwg
DWG. NO. M-100.00 (SHEET 8 OF 9)



REFERENCE:
EXISTING CONDITIONS INFORMATION DEPICTED ON THIS PLAN WAS OBTAINED FROM PLAN ENTITLED: "PARTIAL BOUNDARY & TOPOGRAPHIC SURVEY" NATIONAL GRID PAERDEGAT BASIN GAS PIPELINE CROSSING, BOROUGH OF BROOKLYN, KINGS COUNTRY, NEW YORK, PREPARED BY CHERRY WEBER VAN CLEEF ENGINEERING ASSOCIATES, P.C. DATED: 4-4-2011.

NOTE:
1. FIELD DELINEATED BY WOODARD AND CURRAN ON MARCH 1, 2011.
2. UPON COMPLETION OF CONSTRUCTION, STABILIZE AND SEED THE WORK AREA WITH NYC PARK'S DESIGNATED SEED MIX AND AT DESIGNATED SEED RATE.
3. SEE GEOTECHNICAL REPORT BY CHERRY WEBER ASSOCIATES ISSUED ON FEBRUARY 2, 2011 FOR BORING DETAILS.
4. SEE SURVEY DRAWINGS ISSUED BY CHERRY WEBER AND VAN CLEEF ASSOCIATES DATED 4-4-2011 FOR STATION LINE DETAILS.
5. CONTRACTOR TO EITHER PROTECT OR REPLACE IN KIND THE EXISTING SIGN AND 3 CONCRETE/ BRICK BOLLARDS FOR THE YACHT CLUB ON THE SOUTHEAST CORNER OF WAGE BLVD. AND AVENUE U.

40' 0 40'
BAR SCALE
1" = 45
CHECK GRAPHIC SCALE BEFORE USING

DENNIS M. WALSH
NYS – 058091-1

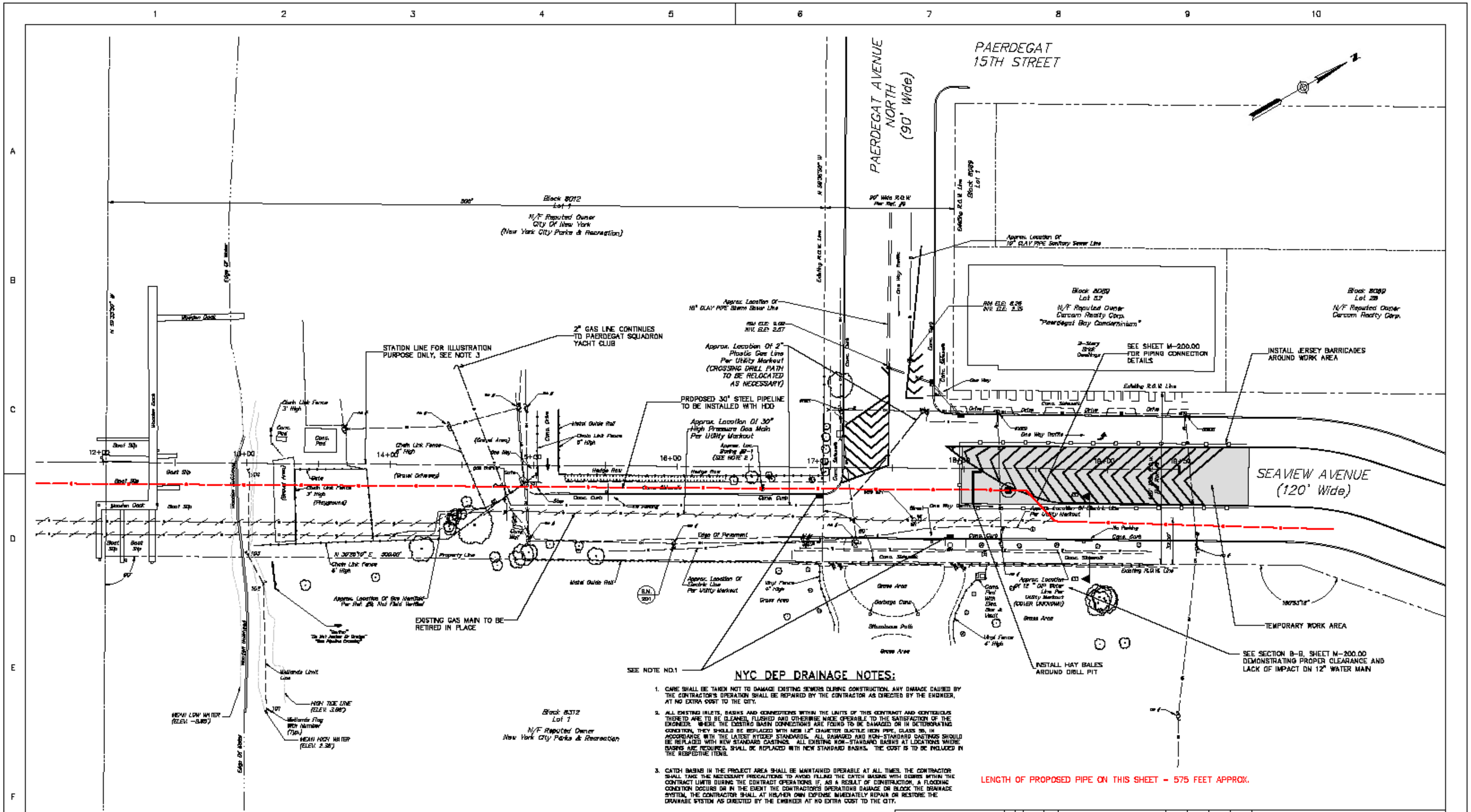
NO.	DATE		DESCRIPTION				
3	1/?/12		CHANGED NOTE NO. 2: ADDED NOTE WOOD FENCE AND LENGTH OF PIPE ON THIS SHEET	[illegible]	[illegible]	[illegible]	[illegible]
2	1/?/12		ADDED NOTE NO. 5	[illegible]	[illegible]	[illegible]	[illegible]
1	12/16/11		MOVED HDD ENTRY POINT, DESIGNED TEMPORARY WORK AREA [illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PAERDEGAT BASIN CROSSING, GAS PIPELINE PROJECT
KINGS COUNTY, BROOKLYN, NY

AVE U & BERGEN AVE SITE PLAN

NATIONAL GRID

DATE: 9/21/11
SCALE: 1"=45'
CAD/LAN FILE NO. 223771-SITE.dwg
DWG. NO. C-100.00 [SHEET 3 OF 9]



NYC DEP DRAINAGE NOTES:

1. CARE SHALL BE TAKEN NOT TO DAMAGE EXISTING SEWERS DURING CONSTRUCTION. ANY DAMAGE CAUSED BY THE CONTRACTOR'S OPERATION SHALL BE REPAIRED BY THE CONTRACTOR AS DIRECTED BY THE ENGINEER, AT NO EXTRA COST TO THE CITY.
2. ALL EXISTING INLETS, BASINS AND CONNECTIONS WITHIN THE LIMITS OF THIS CONTRACT AND CONTIGUOUS THERETO ARE TO BE CLEANED, FLUSHED AND OTHERWISE MADE OPERABLE TO THE SATISFACTION OF THE ENGINEER. WHERE THE EXISTING BASIN CONNECTIONS ARE FOUND TO BE DAMAGED OR IN DETERIORATING CONDITION, THEY SHOULD BE REPLACED WITH NEW 12" DIAMETER DUCTILE IRON PIPE, CLASS 56, IN ACCORDANCE WITH THE LATEST NYCDEP STANDARDS. ALL DAMAGED AND NON-STANDARD CASTINGS SHOULD BE REPLACED WITH NEW STANDARD CASTINGS. ALL EXISTING NON-STANDARD BASINS AT LOCATIONS WHERE BASINS ARE REQUIRED, SHALL BE REPLACED WITH NEW STANDARD BASINS. THE COST IS TO BE INCLUDED IN THE RESPECTIVE ITEMS.
3. CATCH BASINS IN THE PROJECT AREA SHALL BE MAINTAINED OPERABLE AT ALL TIMES. THE CONTRACTOR SHALL TAKE THE NECESSARY PRECAUTIONS TO AVOID FILLING THE CATCH BASINS WITH DEBRIS WITHIN THE CONTRACT LIMITS DURING THE CONTRACT OPERATIONS. IF, AS A RESULT OF CONSTRUCTION, A FLOODING CONDITION OCCURS OR IN THE EVENT THE CONTRACTOR'S OPERATIONS DAMAGE OR BLOCK THE DRAINAGE SYSTEM, THE CONTRACTOR SHALL AT HIS/HER OWN EXPENSE IMMEDIATELY REPAIR OR RESTORE THE DRAINAGE SYSTEM AS DIRECTED BY THE ENGINEER AT NO EXTRA COST TO THE CITY.

LENGTH OF PROPOSED PIPE ON THIS SHEET = 575 FEET APPROX.

REFERENCE:
EXISTING CONDITIONS INFORMATION DEPICTED ON THIS PLAN WAS OBTAINED FROM PLAN ENTITLED: "PARTIAL BOUNDARY & TOPOGRAPHIC SURVEY" NATIONAL GRID PAERDEGAT BASIN GAS PIPELINE CROSSING, BOROUGH OF BROOKLYN, KINGS COUNTRY, NEW YORK, PREPARED BY CHERRY WEBER VAN CLEEF ENGINEERING ASSOCIATES, P.C. DATED: 4-4-2011.

NOTE:
1. CATCH BASIN INSPECTED ON APRIL 8, 2011 AND FOUND TO BE FILLED WITH DEBRIS. CLEAN OUT AND VERIFY DRAINAGE PIPE LOCATIONS BEFORE HDD. ANY CONFLICTS WITH PROPOSED WORK TO BE BROUGHT TO ATTENTION OF OWNER AND ENGINEER.
2. SEE GEOTECHNICAL REPORT BY CHERRY WEBER ASSOCIATES ISSUED ON FEBRUARY 2, 2011 FOR BORING DETAILS.
3. REFER SURVEY DRAWINGS ISSUED BY CHERRY WEBER AND VAN CLEEF ASSOCIATES DATED 4-4-2011 FOR STATION LINE DETAILS.

REFERENCE:
1. THE SEWER SIZES AND MATERIALS HAVE BEEN OBTAINED FROM "BROOKLYN SEWER MAP" GRID NO: D10187 ; DATED 8/21/2008
2. ALL SEWER ELEVATIONS SHOWN ON THE DRAWING REFER TO THE BROOKLYN BOROUGH SEWER DATUM, WHICH IS 1.720' ABOVE THE 0.00 DATUM AT SANDY HOOK MEAN SEA LEVEL AND 0.840' LOWER THAN THE BROOKLYN BOROUGH HIGHWAY DATUM.
3. THE WATER MAIN SIZE AND MATERIAL HAS BEEN OBTAINED FROM "WATER MAPPING" BY NYC DEPARTMENT OF ENVIRONMENTAL PROTECTION. MAP PRINT DATE 1/19/2012

40' 0 40'
BAR SCALE
1" = 45
CHECK GRAPHIC SCALE BEFORE USING

DENNIS M. WALSH
NYS - 058091-1

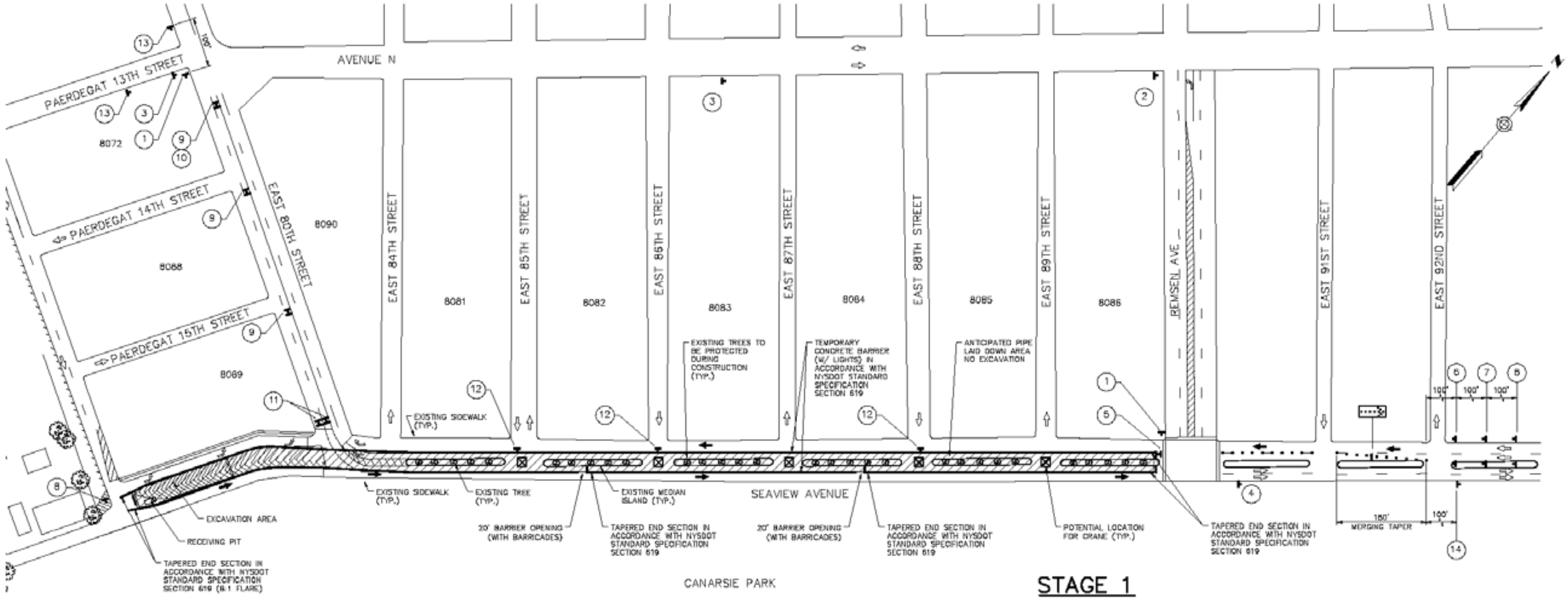
4	4/25/12		REVISED VAULT AT HDD EXIT POINT	MJ	[illegible]	[illegible]	[illegible]
3	[illegible]		ADDED NYC DEP DRAINAGE NOTES AND SECTION B-B LINE	JEC	[illegible]	[illegible]	[illegible]
2	[illegible]		ADDED SIZE AND MATERIAL FOR WATER MAIN	MJ	[illegible]	[illegible]	[illegible]
1	[illegible]		ADDED SIZE, RIM AND INVERT ELEVATION FOR STORM AND SEWER PIPE AND REFERENCE NOTE	MJ	[illegible]	[illegible]	[illegible]
NO.	DATE		DESCRIPTION	[illegible]	[illegible]	[illegible]	[illegible]

PAERDEGAT BASIN CROSSING, GAS PIPELINE PROJECT
KINGS COUNTY, BROOKLYN, NY

SEAVIEW AVE & PAERDEGAT AVE
NORTH SITE PLAN

NATIONAL GRID

DATE: 9/21/11
SCALE: 1"=45'
223771-SITE.dwg
DWG. NO. C-101.0D (SHEET 4 OF 8)



STAGE 1
MPT PLAN DURING PIPE LAYOUT AND WELDING
3 MONTHS DURATION

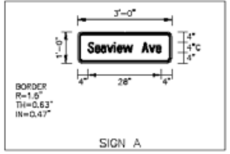
DETOUR SIGN LEGEND

NO.	SIGNS	MUTCD	SIZE
①	TO Seaview Ave Belt Pkwy DETOUR ←	M4-5 SIGN A SIGN B M4-9L	24" x 12" 36" x 12" 30" x 12" 30" x 24"
②	TO Seaview Ave Belt Pkwy DETOUR →	M4-5 SIGN A SIGN B M4-9R	24" x 12" 36" x 12" 30" x 12" 30" x 24"
③	TO Seaview Ave Belt Pkwy DETOUR ↑	M4-5 SIGN A SIGN B M4-9s	24" x 12" 36" x 12" 30" x 12" 30" x 24"
④	TO Seaview Ave Belt Pkwy END DETOUR	M4-5 SIGN A SIGN B M4-8a	24" x 12" 36" x 12" 30" x 12" 24" x 18"
⑤	→	W1-6R	48" x 24"
⑥		W4-2L	36" x 36"
⑦	LEFT LANE CLOSED AHEAD	W20-5	36" x 36"
⑧	ROAD WORK AHEAD	W20-1	36" x 36"
⑨	ROAD CLOSED AHEAD LOCAL TRAFFIC ONLY	R11-3a	60" x 30"
⑩	← DETOUR	M4-10L	48" x 18"
⑪	ROAD CLOSED	R11-2	48" x 30"
⑫	ONE WAY →	R6-1R	36" x 12"
⑬	DETOUR AHEAD	W20-2	36" x 36"
⑭	END ROAD WORK	G20-2	36" x 18"

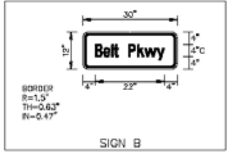
8312

LEGEND:

⇦	ARROW PANEL
▬	ARROW PANEL TRAILER OR SUPPORT
▪	CHANNELIZING DEVICE
▬	TYPE III BARRICADE
⇨	DIRECTION OF TRAFFIC
▶	SIGN, TEMPORARY
▨	WORK AREA
☒	POTENTIAL LOCATION FOR CRANE



SIGN A



SIGN B

NOTES:

1. ALL WORK SHOWN ON THIS DRAWING IS TO BE USED IN CONJUNCTION WITH THE MUTCD GUIDELINES.
2. ALL SIGNS SHALL HAVE A MINIMUM CLEARANCE OF 2'-0" BETWEEN THE EDGE OF THE SIGN AND THE EDGE OF THE LANE.
3. ALL CONSTRUCTION SIGNS SHALL HAVE ORANGE REFLECTORIZED BACKGROUND AND BLACK LETTERS.
4. OCMC APPROVAL IS REQUIRED WHEN STREET IS CLOSED FOR VEHICLE TRAVEL.

Cherry, Weber & Associates
CONSULTING ENGINEERS
20 Gibson Place, Suite 109
Freehold, New Jersey 07728
732.303.8700

WOODARD & CURRAN

LAWRENCE M. DIFFLEY

2/4

PAERDEGAT BASIN CROSSING, GAS PIPELINE PROJECT
KINGS COUNTY, BROOKLYN, NY

SEAVIEW AVE & PAERDEGAT AVE
PRELIMINARY NORTH MPT PLAN

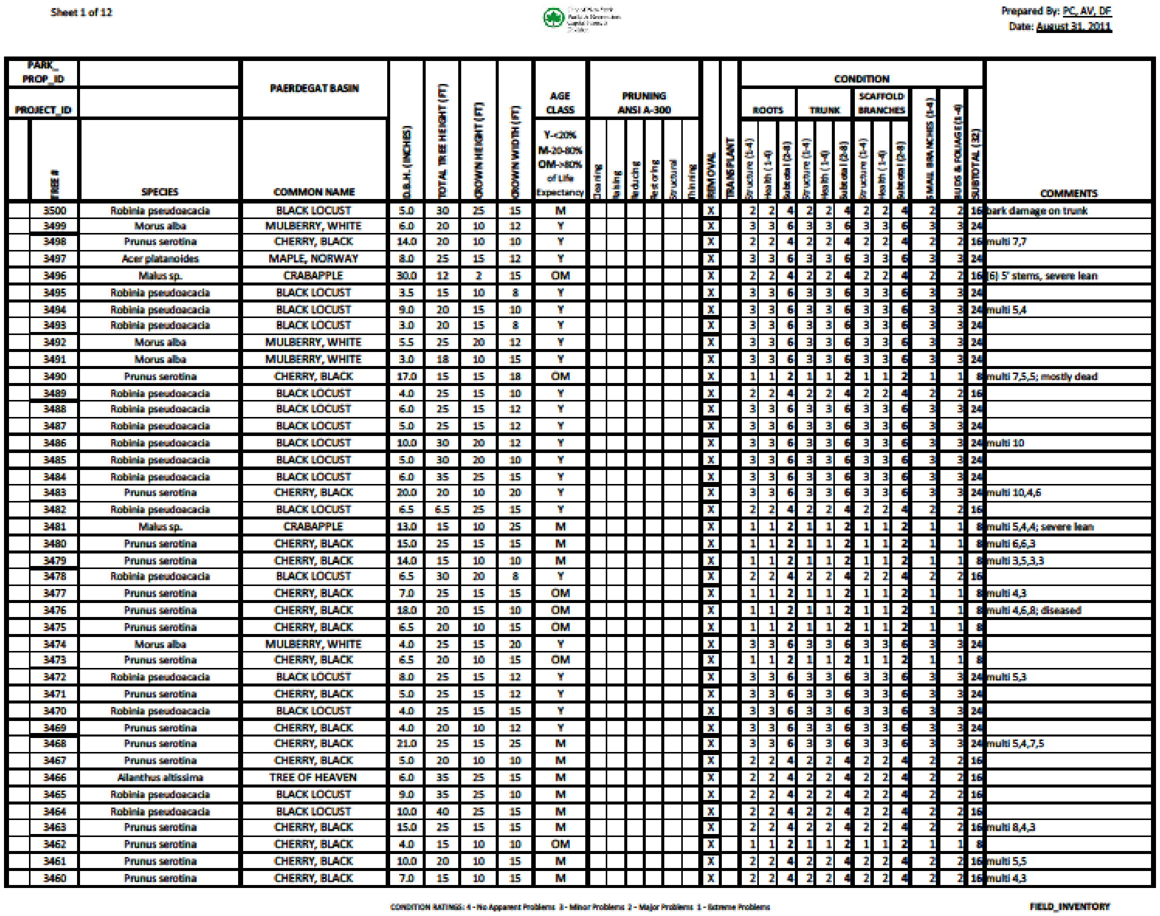
NATIONAL GRID

8/4/11
SCALE: 1"=100'

XX
XX

223771 NYCDPR 2011 –

TREE INVENTORY



Sheet 1 of 12

Prepared By: PC, AV, DF
Date: August 31, 2011

PARK_PROP_ID

PROJECT_ID

PAERDEGAT BASIN

	TREE #	SPECIES	COMMON NAME	D.B.H. (INCHES)	TOTAL TREE HEIGHT (FT)	CROWN HEIGHT (FT)	CROWN WIDTH (FT)	AGE CLASS	PRUNING ANSI A-300						REMOVAL	TRANSPLANT	CONDITION												COMMENTS
																	ROOTS			TRUNK			SCAFFOLD BRANCHES						
								Y-<20% M-20-80% OM->80% of Life Expectancy	Cleaning	Raising	Reducing	Restoring	Structural	Thinning			Structure (1-4)	Health (1-4)	Subtotal (2-8)	Structure (1-4)	Health (1-4)	Subtotal (2-8)	Structure (1-4)	Health (1-4)	Subtotal (2-8)	SMALL BRANCHES (1-4)	BUDS & FOLIAGE (1-4)	SUBTOTAL (32)	
	3500	Robinia pseudoacacia	BLACK LOCUST	5.0	30	25	15	M							X		2	2	4	2	2	4	2	2	4	2	2	16	bark damage on trunk
	3499	Morus alba	MULBERRY, WHITE	6.0	20	10	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3498	Prunus serotina	CHERRY, BLACK	14.0	20	10	10	Y							X		2	2	4	2	2	4	2	2	4	2	2	16	multi 7,7
	3497	Acer platanoides	MAPLE, NORWAY	8.0	25	15	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3496	Malus sp.	CRABAPPLE	30.0	12	2	15	OM							X		2	2	4	2	2	4	2	2	4	2	2	16	(6) 5' stems, severe lean
	3495	Robinia pseudoacacia	BLACK LOCUST	3.5	15	10	8	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3494	Robinia pseudoacacia	BLACK LOCUST	9.0	20	15	10	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	multi 5,4
	3493	Robinia pseudoacacia	BLACK LOCUST	3.0	20	15	8	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3492	Morus alba	MULBERRY, WHITE	5.5	25	20	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3491	Morus alba	MULBERRY, WHITE	3.0	18	10	15	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3490	Prunus serotina	CHERRY, BLACK	17.0	15	15	18	OM							X		1	1	2	1	1	2	1	1	2	1	1	8	multi 7,5,5; mostly dead
	3489	Robinia pseudoacacia	BLACK LOCUST	4.0	25	15	10	Y							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3488	Robinia pseudoacacia	BLACK LOCUST	6.0	25	15	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3487	Robinia pseudoacacia	BLACK LOCUST	5.0	25	15	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3486	Robinia pseudoacacia	BLACK LOCUST	10.0	30	20	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	multi 10
	3485	Robinia pseudoacacia	BLACK LOCUST	5.0	30	20	10	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3484	Robinia pseudoacacia	BLACK LOCUST	6.0	35	25	15	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3483	Prunus serotina	CHERRY, BLACK	20.0	20	10	20	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	multi 10,4,6
	3482	Robinia pseudoacacia	BLACK LOCUST	6.5	6.5	25	15	Y							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3481	Malus sp.	CRABAPPLE	13.0	15	10	25	M							X		1	1	2	1	1	2	1	1	2	1	1	8	multi 5,4,4; severe lean
	3480	Prunus serotina	CHERRY, BLACK	15.0	25	15	15	M							X		1	1	2	1	1	2	1	1	2	1	1	8	multi 6,6,3
	3479	Prunus serotina	CHERRY, BLACK	14.0	15	10	10	M							X		1	1	2	1	1	2	1	1	2	1	1	8	multi 3,5,3,3
	3478	Robinia pseudoacacia	BLACK LOCUST	6.5	30	20	8	Y							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3477	Prunus serotina	CHERRY, BLACK	7.0	25	15	15	OM							X		1	1	2	1	1	2	1	1	2	1	1	8	multi 4,3
	3476	Prunus serotina	CHERRY, BLACK	18.0	20	15	10	OM							X		1	1	2	1	1	2	1	1	2	1	1	8	multi 4,6,8; diseased
	3475	Prunus serotina	CHERRY, BLACK	6.5	20	10	15	OM							X		1	1	2	1	1	2	1	1	2	1	1	8	
	3474	Morus alba	MULBERRY, WHITE	4.0	25	15	20	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3473	Prunus serotina	CHERRY, BLACK	6.5	20	10	15	OM							X		1	1	2	1	1	2	1	1	2	1	1	8	
	3472	Robinia pseudoacacia	BLACK LOCUST	8.0	25	15	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	multi 5,3
	3471	Prunus serotina	CHERRY, BLACK	5.0	25	15	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3470	Robinia pseudoacacia	BLACK LOCUST	4.0	25	15	15	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3469	Prunus serotina	CHERRY, BLACK	4.0	20	10	12	Y							X		3	3	6	3	3	6	3	3	6	3	3	24	
	3468	Prunus serotina	CHERRY, BLACK	21.0	25	15	25	M							X		3	3	6	3	3	6	3	3	6	3	3	24	multi 5,4,7,5
	3467	Prunus serotina	CHERRY, BLACK	5.0	20	10	10	M							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3466	Ailanthus altissima	TREE OF HEAVEN	6.0	35	25	15	M							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3465	Robinia pseudoacacia	BLACK LOCUST	9.0	35	25	10	M							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3464	Robinia pseudoacacia	BLACK LOCUST	10.0	40	25	15	M							X		2	2	4	2	2	4	2	2	4	2	2	16	
	3463	Prunus serotina	CHERRY, BLACK	15.0	25	15	15	M							X		2	2	4	2	2	4	2	2	4	2	2	16	multi 8,4,3
	3462	Prunus serotina	CHERRY, BLACK	4.0	15	10	10	OM							X		1	1	2	1	1	2	1	1	2	1	1	8	
	3461	Prunus serotina	CHERRY, BLACK	10.0	20	10	15	M							X		2	2	4	2	2	4	2	2	4	2	2	16	multi 5,5
	3460	Prunus serotina	CHERRY, BLACK	7.0	15	10	15	M							X		2	2	4	2	2	4	2	2	4	2	2	16	multi 4,3

CONDITION RATINGS: 4 - No Apparent Problems 3 - Minor Problems 2 - Major Problems 1 - Extreme Problems

FIELD_INVENTORY

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Use Pipeline Analysis Tools

TO ASSIST

- Early software included Drillpath by GRI/Maurer
- Sold to Petris in 2008 and later discontinued
- Pipeline Toolbox and Toolbox HDD
- Stress analysis
  - Tensile and Bending Forces
  - Pullback forces with and without water filled pipe

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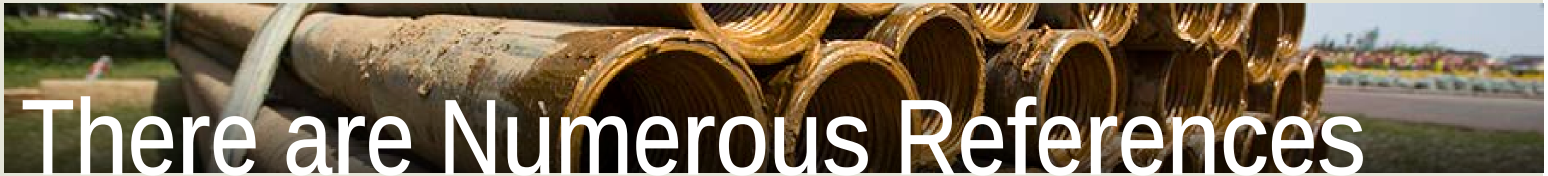

There are Numerous References

AVAILABLE TO ASSIST IN ENGINEERING A TRENCHLESS JOB

- North American Society for Trenchless Technology, www.nastt.org
- HDD Consortium Horizontal Directional Drilling Good Practices Guidelines
- Pipeline Design for Installation by HDD – ASCE
- PRCI HDD Engineering Design Guide
- Pipe Bursting Good Practices – R. David Bennett, PH. D., Bennett – Staheli Engineers, and Samuel T. Ariaratnam, Ph. D, Arizona State University
- Trenchless Technology, Mohammed Najafi, Ph.D., P.E., Sanjiv Gokhale, Ph.D., P.E.

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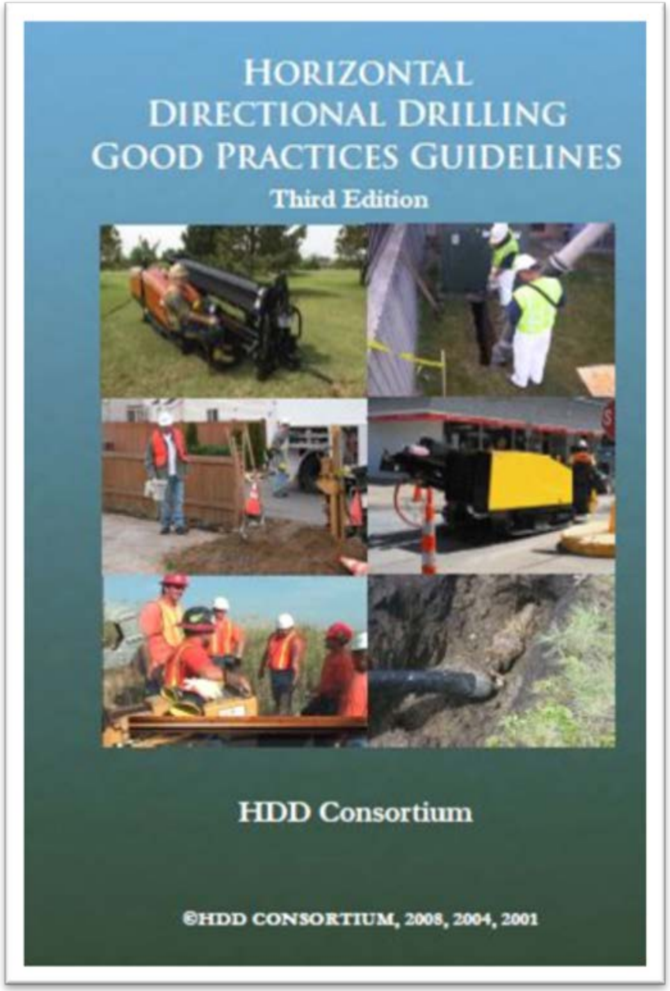
Directional Drilling

BEST PRACTICES



HORIZONTAL
DIRECTIONAL DRILLING
GOOD PRACTICES GUIDELINES
Third Edition

HDD Consortium

©HDD CONSORTIUM, 2008, 2004, 2001

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Future Trenchless Events

- Northeast Gas Association Gas Operations School, June 2-5 at Bryant University in Smithfield, R.I.
- In 2016, the trenchless world goes to Dallas. The NASTT No-Dig 2016 will be at the Gaylord Texan in Grapevine, TX; March 20 – 24, 2016. See http://www.nodigshow.com/
- North American Society for Trenchless Technology (www.nastt.org)

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Mr. Daniel D’Eletto, PE

Manager, Project Engineering & Design

National Grid, USA

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COMMITMENT & INTEGRITY DRIVE RESULTS

Installation of Pipelines by Horizontal Directional Drilling (HDD)

DESIGN GUIDELINES

Presented By: D. D’Eletto
April 10, 2015

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History

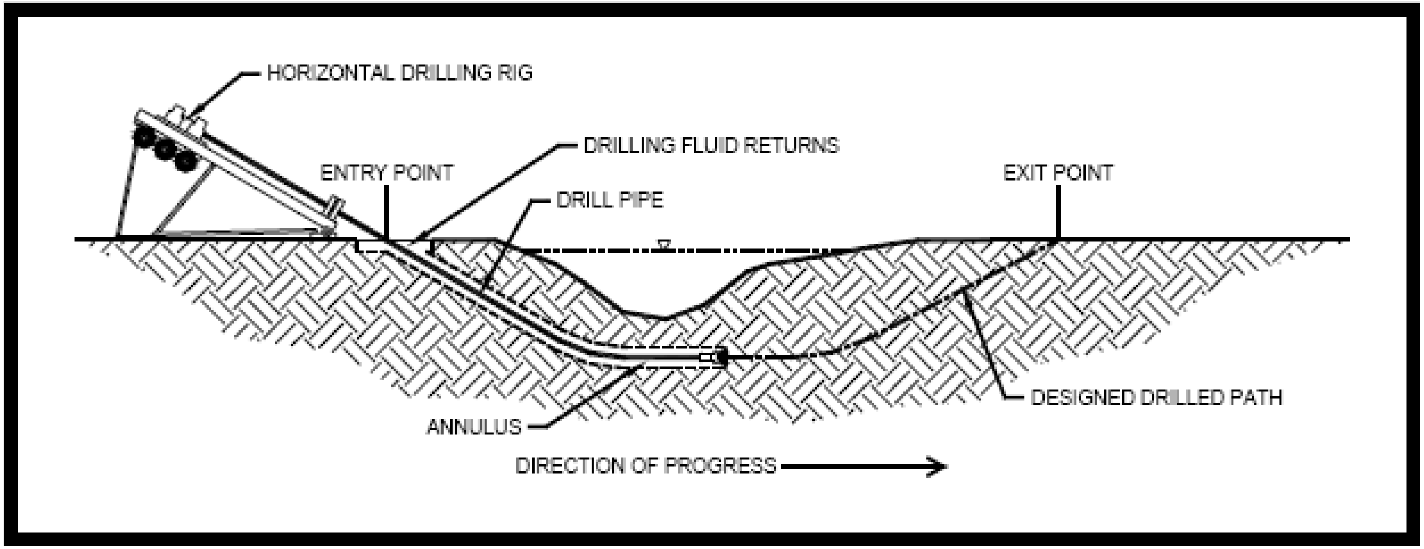
- **HDD –**
  Innovation of the oil well drilling industry.
- **Drill Rig Components Similar –**
  HDD uses an inclined ramp as opposed to vertical mast.
- **Pilot Hole –**
  Same as drilling directional oil well
  (Starts vertical/ends horizontal).
- **Tools Interchangeable –**
  Drill Pipe, downhole tools (cutting heads).
- **Drilling Fluid –**
  Used to transport spoils, reduce friction, stabilize hole, etc.
- **Process Similarities –**
  Process referred to as drilling as
  opposed to boring.

The HDD Process

- **Pilot Hole –**
  Small diameter hole is drilled along a designed drill path.
- **Prereaming –**
  Pilot hole is enlarged to 1.5 times the diameter of the product pipe.
- **Barrel Reaming –**
  Used for swabbing and cleaning the hole.
- **Reaming & Pullback –**
  Product pipe is attached behind reamer and pulled into the enlarged hole.

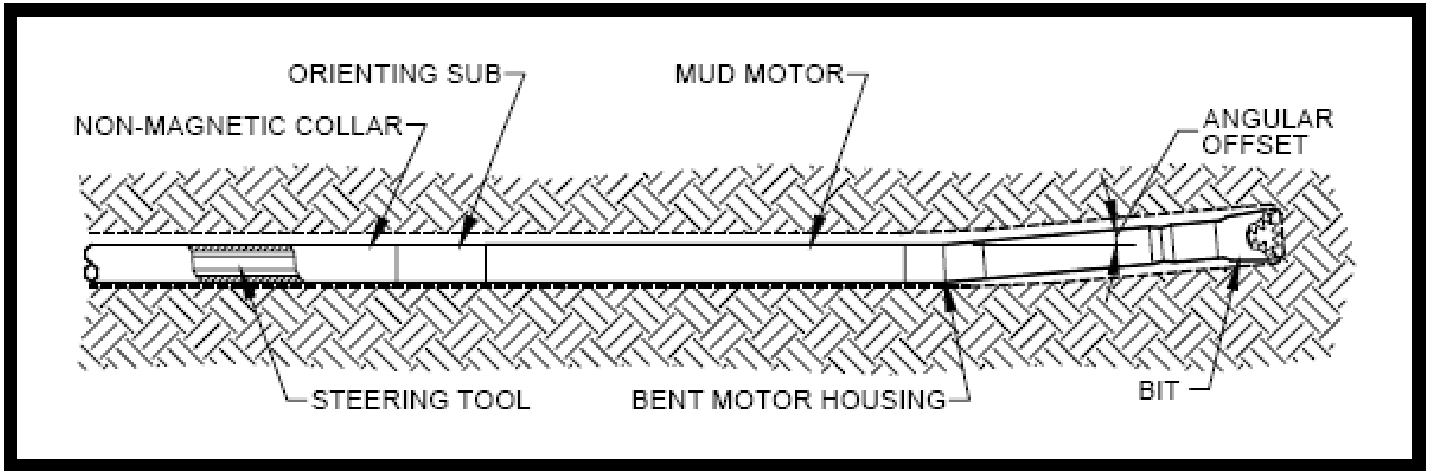
Pilot Hole

- Begins when the bit enters the ground at entry point
- Complete when bit "punches out" at or near exit point
- Progress achieved in soft soils by hydraulic cutting with jet nozzle
- Progress achieved in rock by mechanical cutting with mud motor & bit



Directional Control

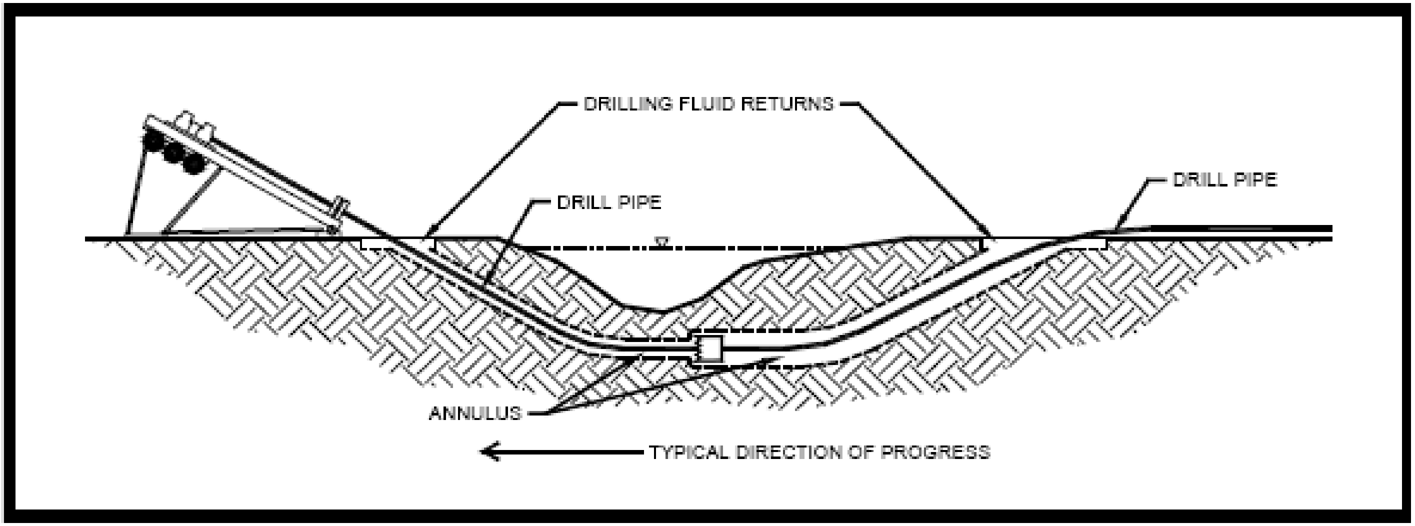
- Control achieved by non-rotating drill string.
- Steering bias created by bend near the leading edge of the drill string.
- Change in direction achieved by rolling drill string so that bend points in desired direction.
- Path calculated using inclination and azimuth readings from steering tool mounted near bit or from surface monitoring system (TruTracker®).
- Drill string continually rotated where directional control not required.



Pilot Hole

Prereaming

- Conducted to enlarge hole prior to pipe installation
- Reamers attached at exit point, then rotated and pulled towards the rig to enlarge the hole.
- Reamers consist of circular array of cutters and fluid jets.
- Drill pipe is added behind the reamers as they progress towards the drill rig.
- Insures pipe string always maintained in the hole.
- Also possible to ream away from the rig.



Reamers

Jet Reamer

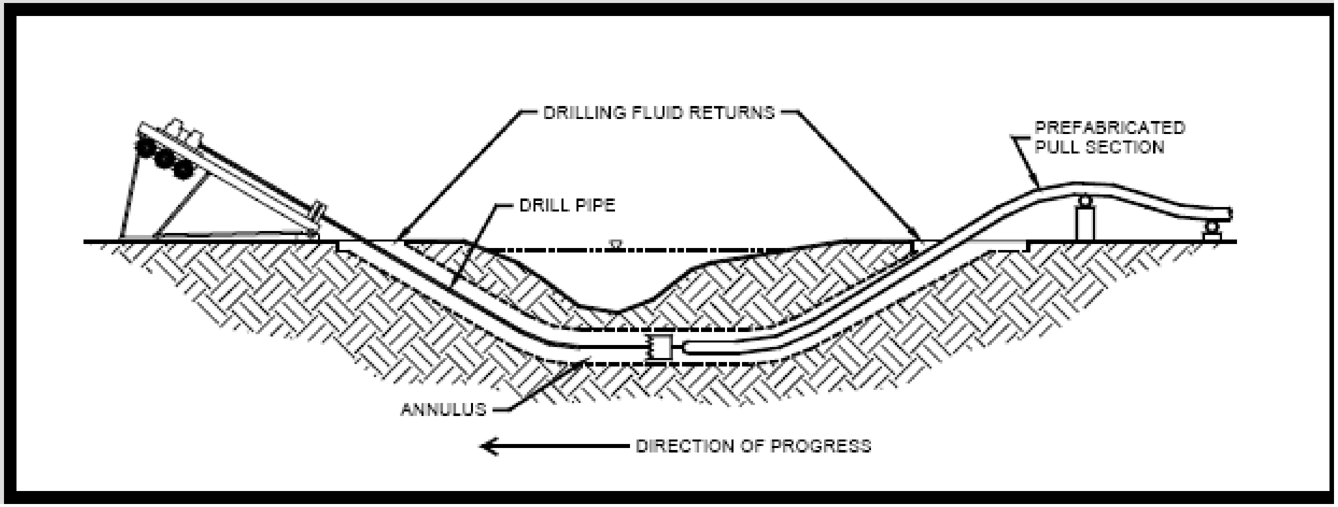
Rock Cutter

Barrel Reamer

Rock Cutter

Pullback

- Prefabricated pipe attached behind reamer at exit point and pulled to rig.
- Swivel/thrust bearing placed between pipe section & reamer to minimize torsion.
- Pull section supported using combination of roller stands and pipe handling equipment (sidebooms, cranes, roller cradles) to minimize tensile forces in pipe.
- Laydown area needed beyond exit point must equal length of drill for continuous length of prefabricated pipe. Temporary ramps can be constructed for continuous pipe or split in half and welded prior to the day of pullback.



Pullback

Buoyancy Control

- **Positive Buoyancy –** The weight of the volume of the fluid displaced by an object is greater than the dead weight of the object.
- Density of drilling fluid (80-90 lbs/cu.ft.) greater than water (62.4 lbs/cu.ft)
- Uplift forces for large diameter pipelines can be substantial.
- Buoyancy control used for pipe 30 inches or over in diameter.
- Most common control is to fill pipe with water.

Feasibility Considerations

- **Technically Feasible –**
  If it can be installed using existing tools and techniques regardless of cost.
- **Contractually Feasible –**
  If cost can be accurately estimated to allow contractors to submit lump sum bids.
- **Economically Feasible –**
  If its installation cost is less than the cost of an equivalent construction method.

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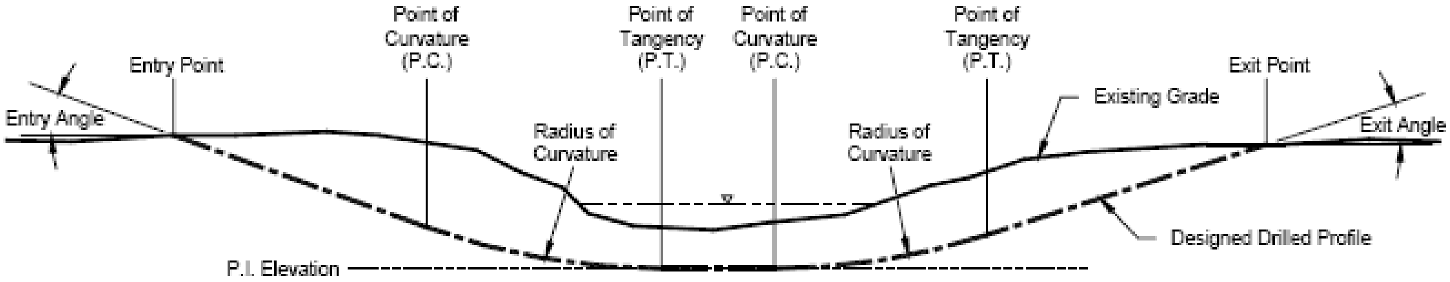
HDD Feasibility- Governed by Three Parameters

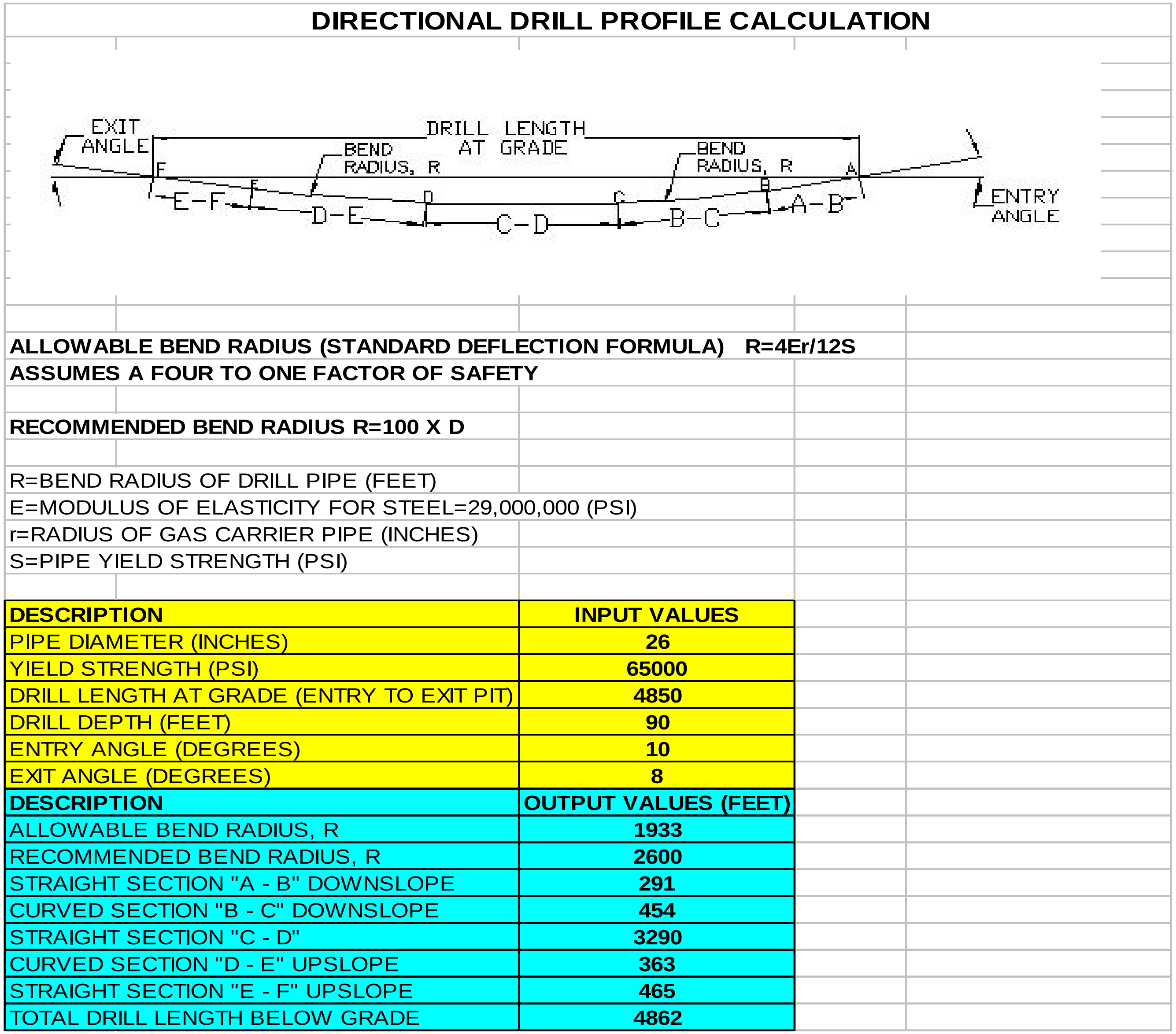
- **Pipe Diameter –**
  Welded steel pipelines up to 56 inches.
- **Length –**
  Smaller diameter welded steel pipelines up to 7,000 feet.
- **Subsurface Material –**
  Must be able to create open hole in rock or cohesive soils or fluidized condition in cohesionless soils such as sand or silt. Coarse grain, excessive rock strength/ hardness (50,000 psi), & solution cavities in bedrock prevent these two conditions.

Drill Profile Segments

- Entry Point (Rig Side) & Entry Angle – Optimum 10-12 degrees (Rigs 10-18 degrees)
- Downslope – Min. 30 feet or one drill rod length
- Point of Curvature (P.C.)
- Radius of Curvature – 100 x D Recommended
- Point of Tangent (P.T.)
- Horizontal – Min. 30 feet or one drill rod length
- Point of Curvature (P.C.)
- Radius of Curvature – 100 x D Recommended
- Point of Tangent (P.T.)
- Upslope –Min. 30 feet or one drill rod length
- Exit Point (Pipe Side) & Exit Angle – Optimum 8 degrees
- P.I. Elevation or Depth of Cover – Min. 30 feet



Drill Profile Calculation



DIRECTIONAL DRILL PROFILE CALCULATION

ALLOWABLE BEND RADIUS (STANDARD DEFLECTION FORMULA)   R=4Er/12S

ASSUMES A FOUR TO ONE FACTOR OF SAFETY

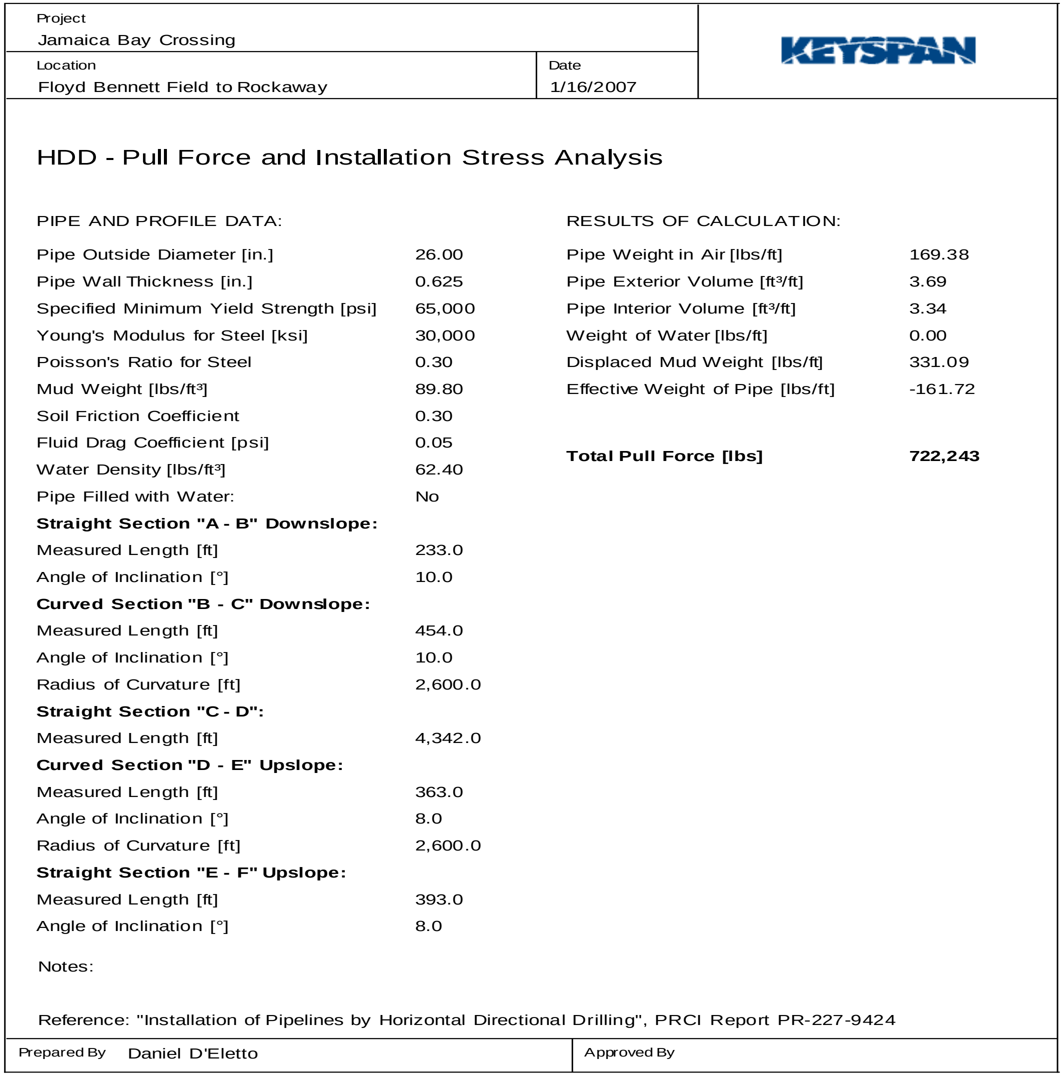
RECOMMENDED BEND RADIUS R=100 X D

R=BEND RADIUS OF DRILL PIPE (FEET)
E=MODULUS OF ELASTICITY FOR STEEL=29,000,000 (PSI)
r=RADIUS OF GAS CARRIER PIPE (INCHES)
S=PIPE YIELD STRENGTH (PSI)

DESCRIPTION	**INPUT VALUES**
PIPE DIAMETER (INCHES)	**26**
YIELD STRENGTH (PSI)	**65000**
DRILL LENGTH AT GRADE (ENTRY TO EXIT PIT)	**4850**
DRILL DEPTH (FEET)	**90**
ENTRY ANGLE (DEGREES)	**10**
EXIT ANGLE (DEGREES)	**8**

DESCRIPTION	**OUTPUT VALUES (FEET)**
ALLOWABLE BEND RADIUS, R	**1933**
RECOMMENDED BEND RADIUS, R	**2600**
STRAIGHT SECTION "A - B" DOWNSLOPE	**291**
CURVED SECTION "B - C" DOWNSLOPE	**454**
STRAIGHT SECTION "C - D"	**3290**
CURVED SECTION "D - E" UPSLOPE	**363**
STRAIGHT SECTION "E - F" UPSLOPE	**465**
TOTAL DRILL LENGTH BELOW GRADE	**4862**

Pull Force Analysis – Pipe Empty



Project
Jamaica Bay Crossing

KEYSPAN

Location
Floyd Bennett Field to Rockaway

Date
1/16/2007

HDD - Pull Force and Installation Stress Analysis

PIPE AND PROFILE DATA:

Pipe Outside Diameter [in.]	26.00
Pipe Wall Thickness [in.]	0.625
Specified Minimum Yield Strength [psi]	65,000
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Mud Weight [lbs/ft³]	89.80
Soil Friction Coefficient	0.30
Fluid Drag Coefficient [psi]	0.05
Water Density [lbs/ft³]	62.40
Pipe Filled with Water:	No
Straight Section "A - B" Downslope:	
Measured Length [ft]	233.0
Angle of Inclination [°]	10.0
Curved Section "B - C" Downslope:	
Measured Length [ft]	454.0
Angle of Inclination [°]	10.0
Radius of Curvature [ft]	2,600.0
Straight Section "C - D":	
Measured Length [ft]	4,342.0
Curved Section "D - E" Upslope:	
Measured Length [ft]	363.0
Angle of Inclination [°]	8.0
Radius of Curvature [ft]	2,600.0
Straight Section "E - F" Upslope:	
Measured Length [ft]	393.0
Angle of Inclination [°]	8.0

RESULTS OF CALCULATION:

Pipe Weight in Air [lbs/ft]	169.38
Pipe Exterior Volume [ft³/ft]	3.69
Pipe Interior Volume [ft³/ft]	3.34
Weight of Water [lbs/ft]	0.00
Displaced Mud Weight [lbs/ft]	331.09
Effective Weight of Pipe [lbs/ft]	-161.72
Total Pull Force [lbs]	**722,243**

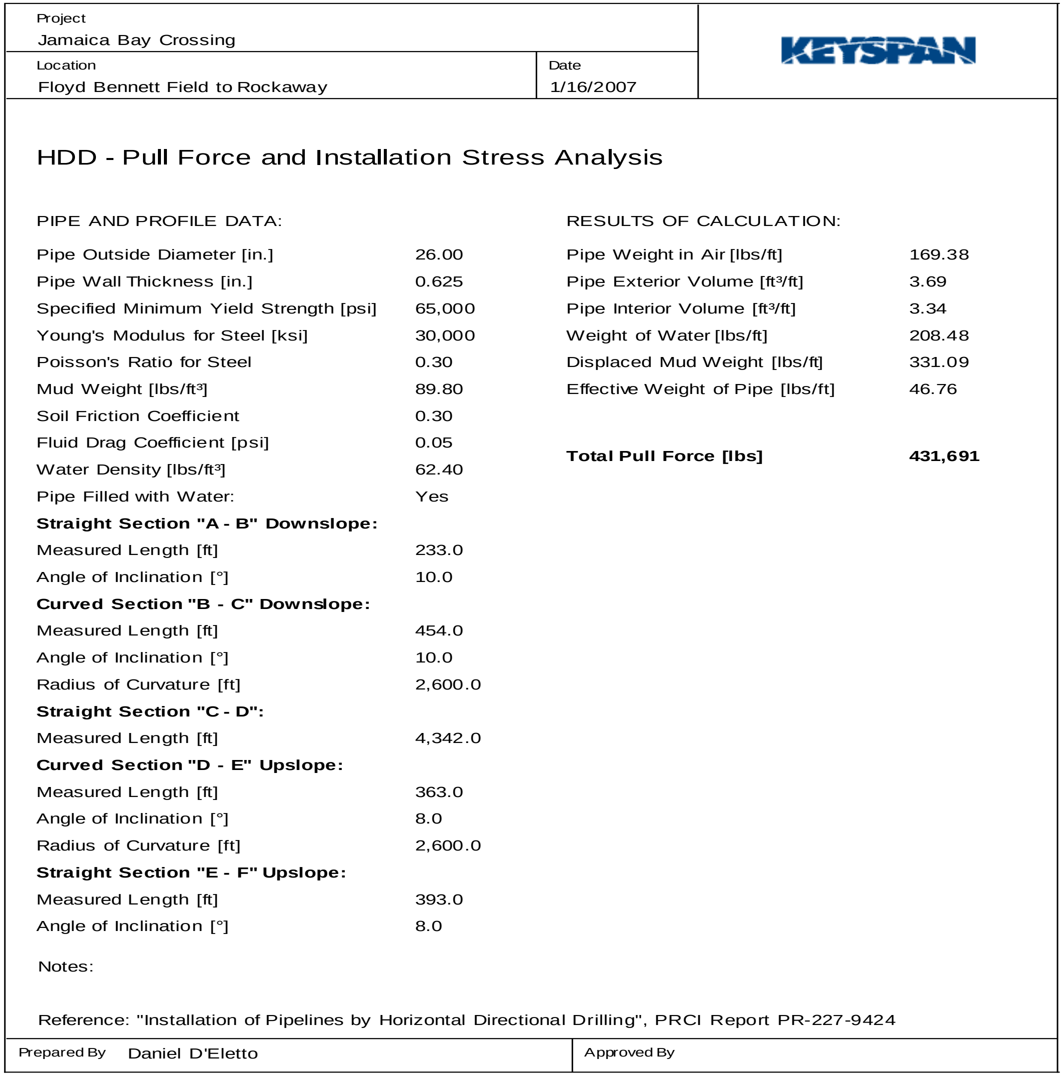
Notes:

Reference: "Installation of Pipelines by Horizontal Directional Drilling", PRCI Report PR-227-9424

Prepared By Daniel D'Eletto

Approved By

Pull Force – Pipe Filled with Water



Project
Jamaica Bay Crossing

Location
Floyd Bennett Field to Rockaway

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1/16/2007

KEYSPAN

HDD - Pull Force and Installation Stress Analysis

PIPE AND PROFILE DATA:

Pipe Outside Diameter [in.]	26.00
Pipe Wall Thickness [in.]	0.625
Specified Minimum Yield Strength [psi]	65,000
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Mud Weight [lbs/ft³]	89.80
Soil Friction Coefficient	0.30
Fluid Drag Coefficient [psi]	0.05
Water Density [lbs/ft³]	62.40
Pipe Filled with Water:	Yes
Straight Section "A - B" Downslope:	
Measured Length [ft]	233.0
Angle of Inclination [°]	10.0
Curved Section "B - C" Downslope:	
Measured Length [ft]	454.0
Angle of Inclination [°]	10.0
Radius of Curvature [ft]	2,600.0
Straight Section "C - D":	
Measured Length [ft]	4,342.0
Curved Section "D - E" Upslope:	
Measured Length [ft]	363.0
Angle of Inclination [°]	8.0
Radius of Curvature [ft]	2,600.0
Straight Section "E - F" Upslope:	
Measured Length [ft]	393.0
Angle of Inclination [°]	8.0

RESULTS OF CALCULATION:

Pipe Weight in Air [lbs/ft]	169.38
Pipe Exterior Volume [ft³/ft]	3.69
Pipe Interior Volume [ft³/ft]	3.34
Weight of Water [lbs/ft]	208.48
Displaced Mud Weight [lbs/ft]	331.09
Effective Weight of Pipe [lbs/ft]	46.76
Total Pull Force [lbs]	**431,691**

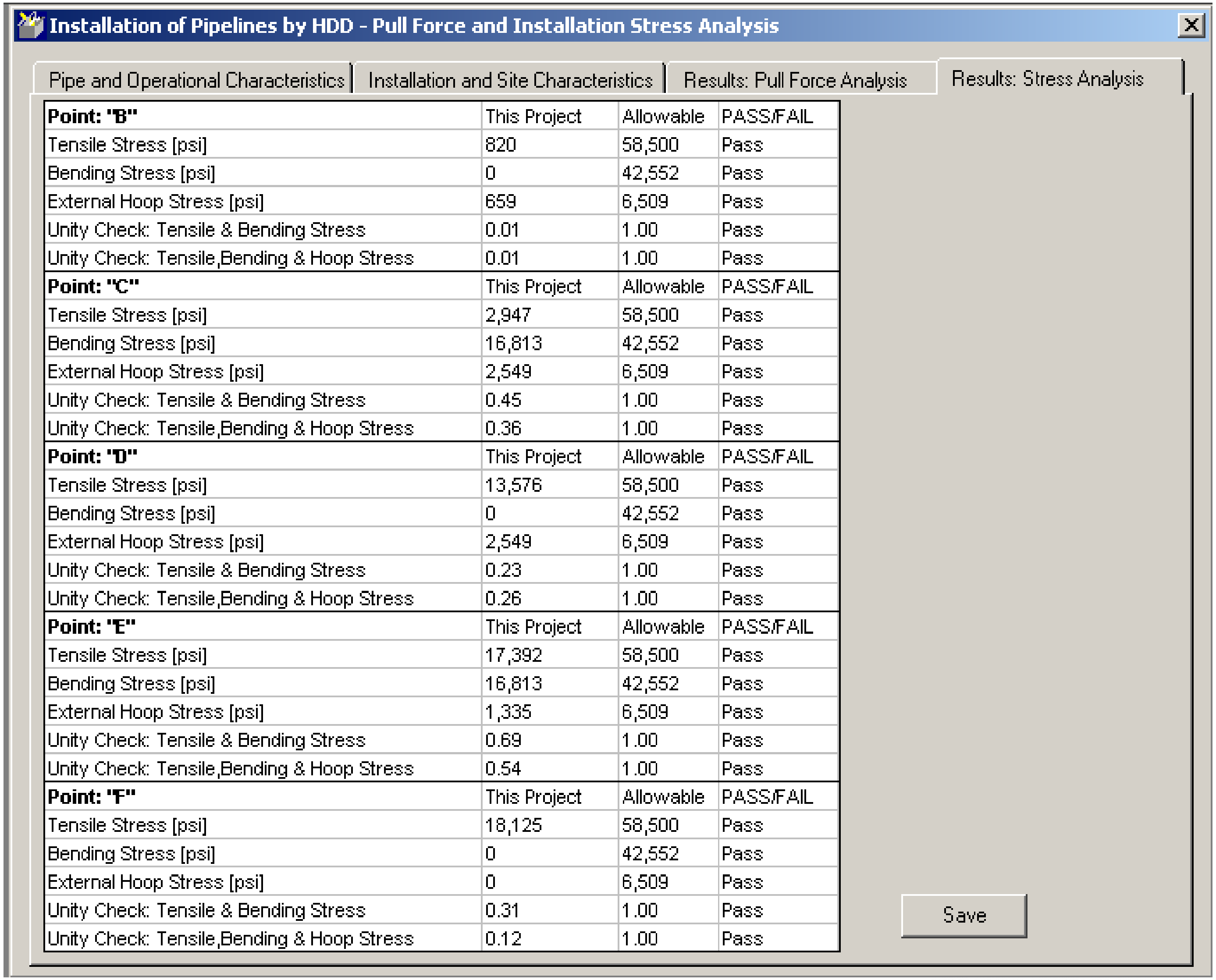
Notes:

Reference: "Installation of Pipelines by Horizontal Directional Drilling", PRCI Report PR-227-9424

Prepared By Daniel D'Eletto

Approved By

Stress Analysis



Installation of Pipelines by HDD - Pull Force and Installation Stress Analysis

Point: "B"	This Project	Allowable	PASS/FAIL
Tensile Stress [psi]	820	58,500	Pass
Bending Stress [psi]	0	42,552	Pass
External Hoop Stress [psi]	659	6,509	Pass
Unity Check: Tensile & Bending Stress	0.01	1.00	Pass
Unity Check: Tensile,Bending & Hoop Stress	0.01	1.00	Pass
Point: "C"	This Project	Allowable	PASS/FAIL
Tensile Stress [psi]	2,947	58,500	Pass
Bending Stress [psi]	16,813	42,552	Pass
External Hoop Stress [psi]	2,549	6,509	Pass
Unity Check: Tensile & Bending Stress	0.45	1.00	Pass
Unity Check: Tensile,Bending & Hoop Stress	0.36	1.00	Pass
Point: "D"	This Project	Allowable	PASS/FAIL
Tensile Stress [psi]	13,576	58,500	Pass
Bending Stress [psi]	0	42,552	Pass
External Hoop Stress [psi]	2,549	6,509	Pass
Unity Check: Tensile & Bending Stress	0.23	1.00	Pass
Unity Check: Tensile,Bending & Hoop Stress	0.26	1.00	Pass
Point: "E"	This Project	Allowable	PASS/FAIL
Tensile Stress [psi]	17,392	58,500	Pass
Bending Stress [psi]	16,813	42,552	Pass
External Hoop Stress [psi]	1,335	6,509	Pass
Unity Check: Tensile & Bending Stress	0.69	1.00	Pass
Unity Check: Tensile,Bending & Hoop Stress	0.54	1.00	Pass
Point: "F"	This Project	Allowable	PASS/FAIL
Tensile Stress [psi]	18,125	58,500	Pass
Bending Stress [psi]	0	42,552	Pass
External Hoop Stress [psi]	0	6,509	Pass
Unity Check: Tensile & Bending Stress	0.31	1.00	Pass
Unity Check: Tensile,Bending & Hoop Stress	0.12	1.00	Pass

Subsurface Material

- **Coarse Grained –**
  Gravel, Cobbles and Boulders cannot be fluidized for removal nor stable enough for open hole. Gravel can bind bit.
- **Excessive Rock Strength –**
  May deflect drill string, wear bits, slow drill rates, resulting in extended construction duration.
- **Poor Rock Quality –**
  Vertical Rock fissures cause fracouts
  (drilling fluid surfacing).

Soil Borings

- **Intervals –**
  Provide contractor with as many as possible
  (Min. 500’ intervals)!
- **Locations –**
  Use 30-50’ clearance. Borings taken along drill path centerline can cause Fracouts. Grout if unavoidable.
- **Depth –**
  20 feet below drill path elevation.
- **Soil Sampling –**
  Collect split spoon soil samples @ 5 foot elevations.

Lab Analysis

- **Soil Classification –**
  Unified Soil Classification System (USCS) ASTM D 2487.
- **Sands/Silts (SW thru OH) –**
  Only need classification & blow counts.
- **Coarse Grained Gravels (GC thru GW) –**
  Need sieve analysis ASTM D-422.
- **Rock –**
  Compressive strength ASTM D 2938

HDD Feasibility
Sieve Analysis Gravel %

- **Loose - dense sand –**
  0 to 30% - Good -Excellent
- **Dense gravelly sand –**
  30 to 50% – Marginal
- **Dense sandy gravel –**
  50 to 85% – Questionable
- **Dense gravel –**
  85 to 100% – Unacceptable

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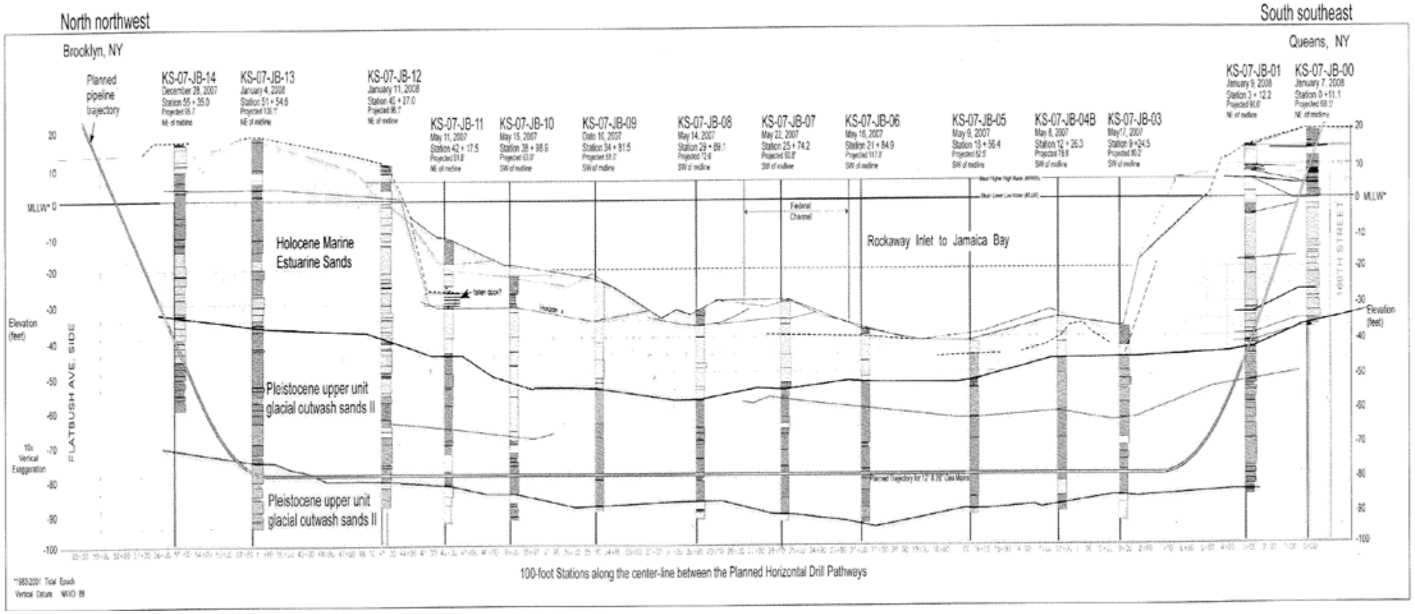
Overlay Borings on Drill Profile



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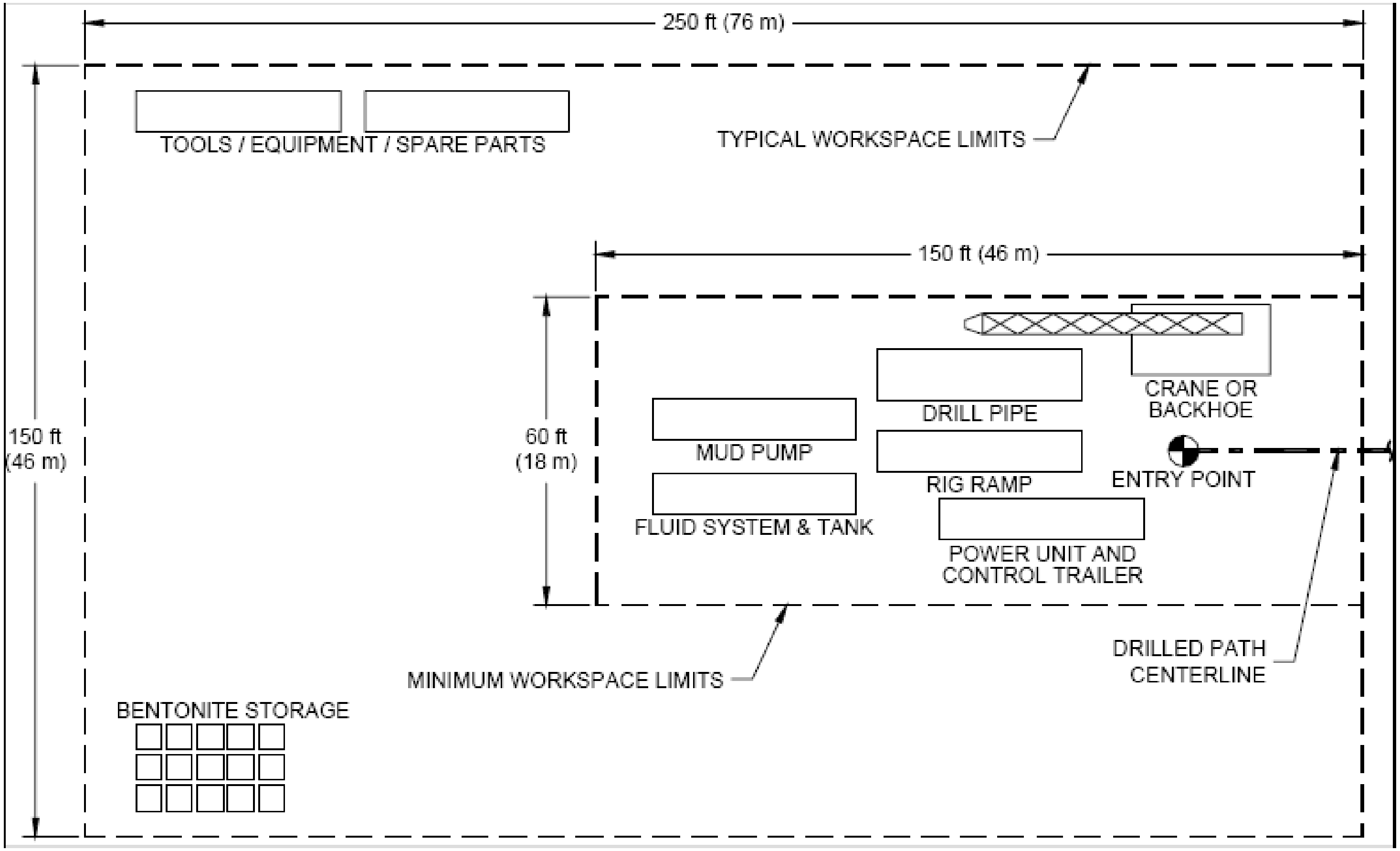
Drill Entry Workspace



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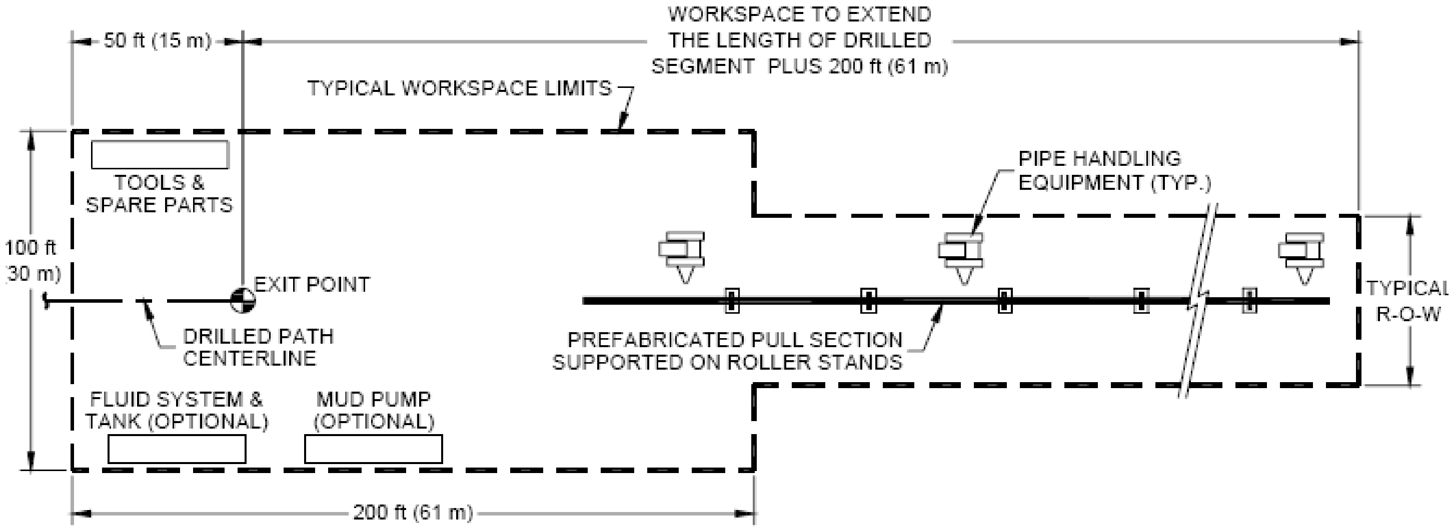
Drill Entry Workspace

Drill Rig

Drill Entry Winter Enclosure

Drill Exit Workspace



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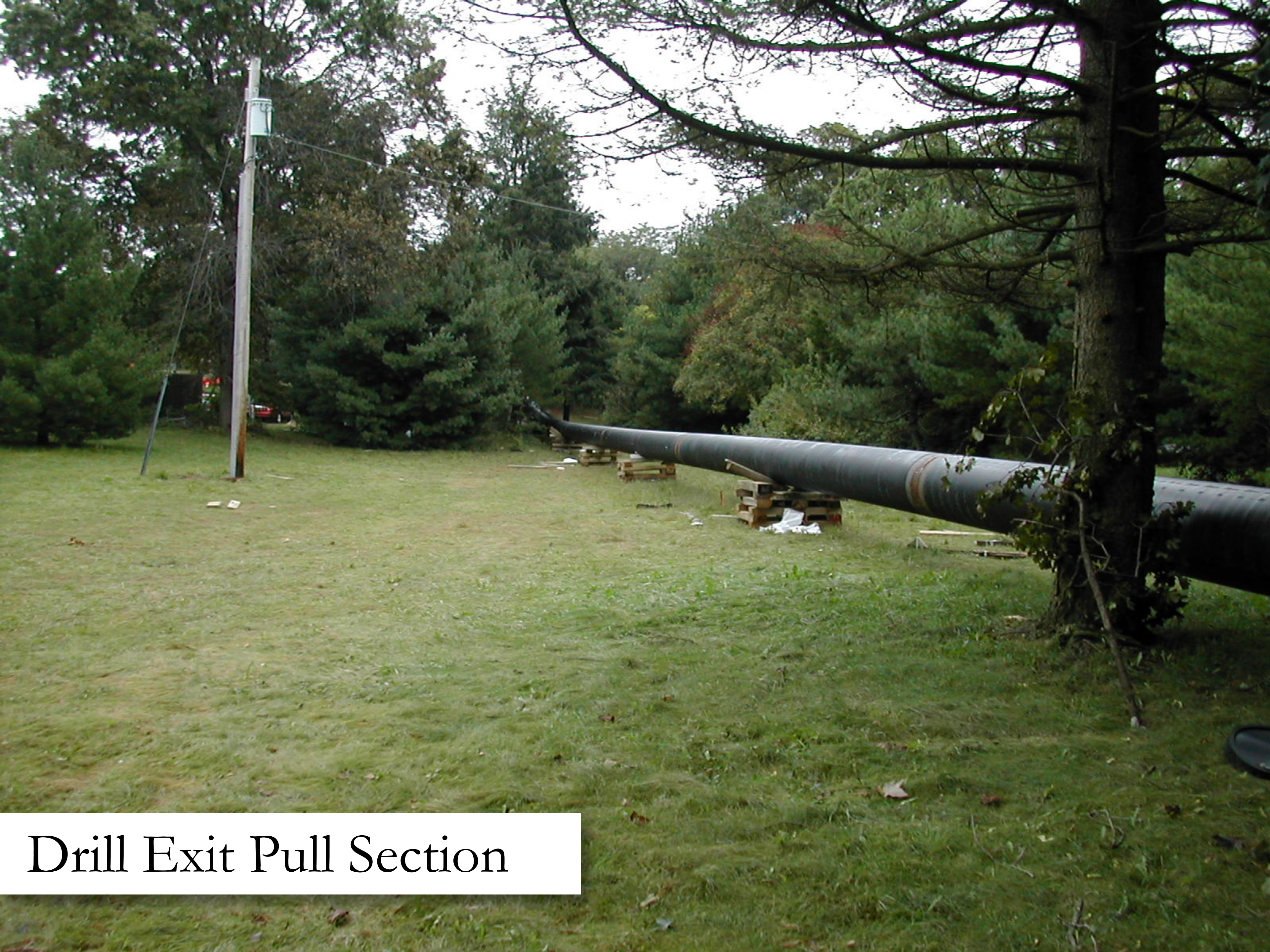
Drill Exit Workspace

Drill Exit Pull Section



Drill Exit Pull Section

Frac-outs

Pipe Corrosion Coatings

- **Qualities –**
  High abrasion resistance w/smooth hard surface.
- **Common Types –**
  HDPE (PRITEC), thin film fusion bonded epoxy (FBE).
- **Coating Armor –**
  Use Powercrete over FBE for gravel/rock.
- **Thickness –**
  HDPE - 80 Mils, FBE/Powercrete -20/60 Mils.
- **Field Joints –**
  Raychem DIRAX Shrink Sleeve for HDPE, Powercrete J for FBE/Powercrete.

Pull Section Integrity Tests

- **Welds –**
  100% X-Ray
- **Pre Drill Hydrotest –**
  4 Hours Above Ground @ 2 Times MAOP
- **Post Drill –**
  Caliper Pig for dents > 2% pipe O.D.
- **Post Drill –**
  Hydrotest for 12 hours @ 2 times MAOP

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HDD Cost Summary

- Mobilization
- Rig-Up
- Pilot Hole
- Ream
- Swab
- Pullback
- Rig Down
- Demobilization
- Drilling Mud
- Does not include site preparation, pipe fabrication, stringing, welding, radiography, coating, hydrotest, etc.

HDD Production Rates < 30” Diameter in Sand

- **Pilot Hole -** 50 - 60 ft./hr
- **Ream -** 2-3 ft./min.
- **Swab -** 10 ft./min.
- **Pullback -** 8 ft./min.
- **Duration -** Use 10 hour shift/day
- **Drill Crew -** $13,172/day
- **Pull Back Crew -** $8,800/day

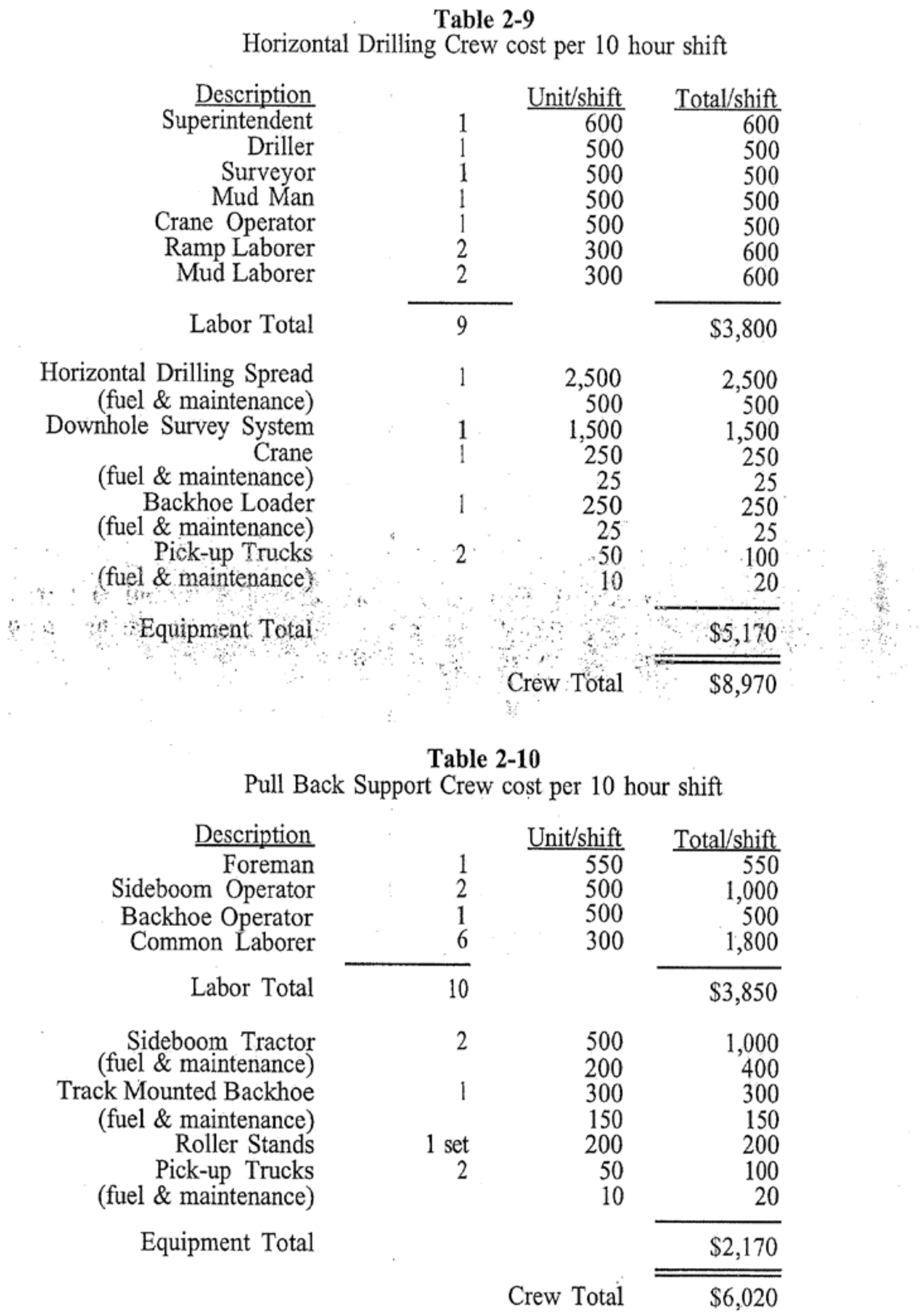
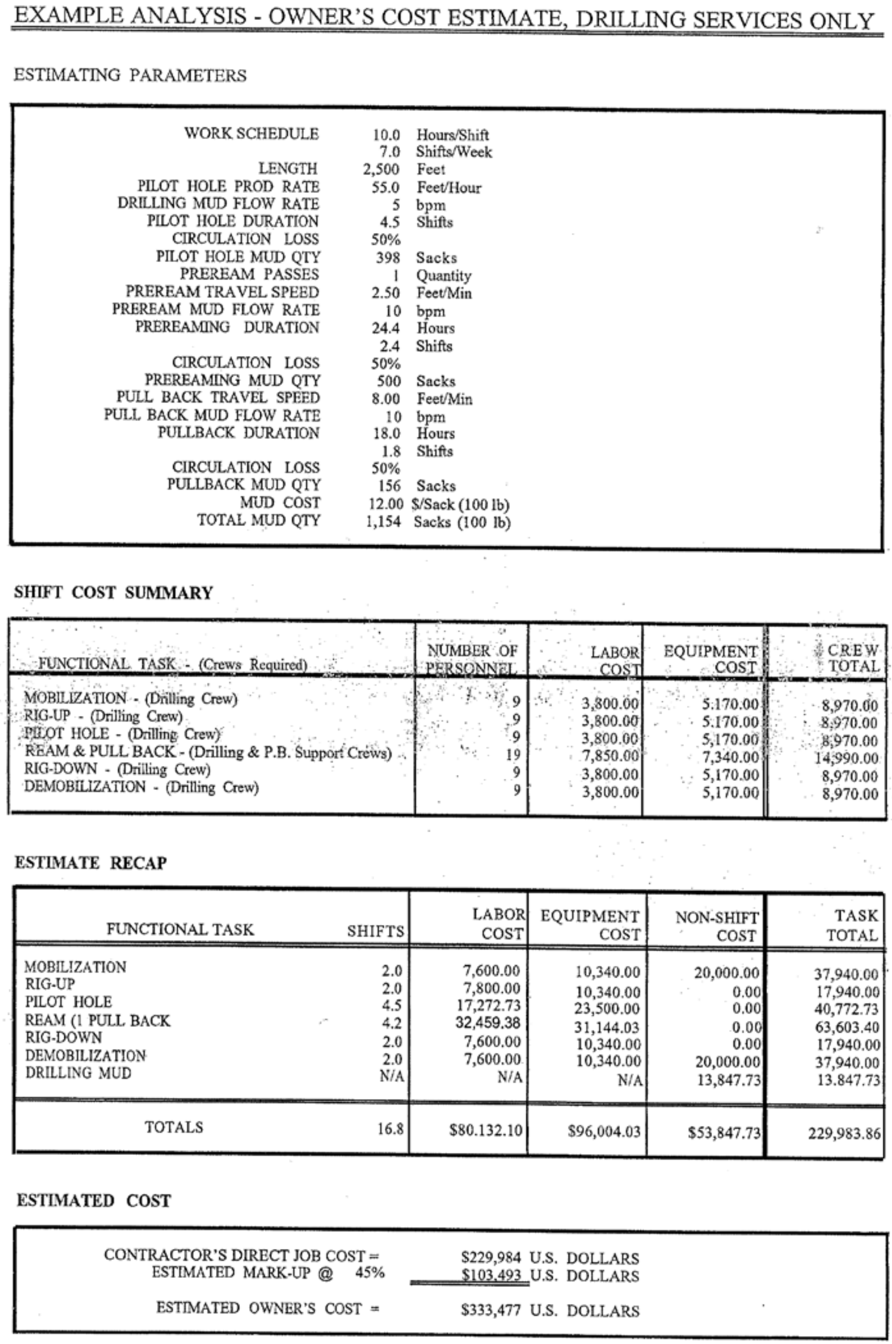


Table 2-9
Horizontal Drilling Crew cost per 10 hour shift

Description		Unit/shift	Total/shift
Superintendent	1	600	600
Driller	1	500	500
Surveyor	1	500	500
Mud Man	1	500	500
Crane Operator	1	500	500
Ramp Laborer	2	300	600
Mud Laborer	2	300	600
Labor Total	9		$3,800
Horizontal Drilling Spread	1	2,500	2,500
(fuel & maintenance)		500	500
Downhole Survey System	1	1,500	1,500
Crane	1	250	250
(fuel & maintenance)		25	25
Backhoe Loader	1	250	250
(fuel & maintenance)		25	25
Pick-up Trucks	2	50	100
(fuel & maintenance)		10	20
Equipment Total			$5,170
		Crew Total	$8,970

Table 2-10
Pull Back Support Crew cost per 10 hour shift

Description		Unit/shift	Total/shift
Foreman	1	550	550
Sideboom Operator	2	500	1,000
Backhoe Operator	1	500	500
Common Laborer	6	300	1,800
Labor Total	10		$3,850
Sideboom Tractor	2	500	1,000
(fuel & maintenance)		200	400
Track Mounted Backhoe	1	300	300
(fuel & maintenance)		150	150
Roller Stands	1 set	200	200
Pick-up Trucks	2	50	100
(fuel & maintenance)		10	20
Equipment Total			$2,170
		Crew Total	$6,020



EXAMPLE ANALYSIS - OWNER'S COST ESTIMATE, DRILLING SERVICES ONLY

ESTIMATING PARAMETERS

WORK SCHEDULE	10.0	Hours/Shift
	7.0	Shifts/Week
LENGTH	2,500	Feet
PILOT HOLE PROD RATE	55.0	Feet/Hour
DRILLING MUD FLOW RATE	5	bpm
PILOT HOLE DURATION	4.5	Shifts
CIRCULATION LOSS	50%	
PILOT HOLE MUD QTY	398	Sacks
PREREAM PASSES	1	Quantity
PREREAM TRAVEL SPEED	2.50	Feet/Min
PREREAM MUD FLOW RATE	10	bpm
PREREAMING DURATION	24.4	Hours
	2.4	Shifts
CIRCULATION LOSS	50%	
PREREAMING MUD QTY	500	Sacks
PULL BACK TRAVEL SPEED	8.00	Feet/Min
PULL BACK MUD FLOW RATE	10	bpm
PULLBACK DURATION	18.0	Hours
	1.8	Shifts
CIRCULATION LOSS	50%	
PULLBACK MUD QTY	156	Sacks
MUD COST	12.00	$/Sack (100 lb)
TOTAL MUD QTY	1,154	Sacks (100 lb)

SHIFT COST SUMMARY

FUNCTIONAL TASK - (Crews Required)	NUMBER OF PERSONNEL	LABOR COST	EQUIPMENT COST	CREW TOTAL
MOBILIZATION - (Drilling Crew)	9	3,800.00	5,170.00	8,970.00
RIG-UP - (Drilling Crew)	9	3,800.00	5,170.00	8,970.00
PILOT HOLE - (Drilling Crew)	9	3,800.00	5,170.00	8,970.00
REAM & PULL BACK - (Drilling & P.B. Support Crews)	19	7,850.00	7,340.00	14,990.00
RIG-DOWN - (Drilling Crew)	9	3,800.00	5,170.00	8,970.00
DEMOBILIZATION - (Drilling Crew)	9	3,800.00	5,170.00	8,970.00

ESTIMATE RECAP

FUNCTIONAL TASK	SHIFTS	LABOR COST	EQUIPMENT COST	NON-SHIFT COST	TASK TOTAL
MOBILIZATION	2.0	7,600.00	10,340.00	20,000.00	37,940.00
RIG-UP	2.0	7,800.00	10,340.00	0.00	17,940.00
PILOT HOLE	4.5	17,272.73	23,500.00	0.00	40,772.73
REAM (1 PULL BACK	4.2	32,459.38	31,144.03	0.00	63,603.40
RIG-DOWN	2.0	7,600.00	10,340.00	0.00	17,940.00
DEMOBILIZATION	2.0	7,600.00	10,340.00	20,000.00	37,940.00
DRILLING MUD	N/A	N/A	N/A	13,847.73	13.847.73
TOTALS	16.8	$80.132.10	$96,004.03	$53,847.73	229,983.86

ESTIMATED COST

CONTRACTOR'S DIRECT JOB COST =	$229,984 U.S. DOLLARS
ESTIMATED MARK-UP @ 45%	$103,493 U.S. DOLLARS
ESTIMATED OWNER'S COST =	$333,477 U.S. DOLLARS

THANK YOU!

QUESTIONS?

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