Draft Design Report

HAYDEN ROAD STORMDRAIN

The Desert Greenbelt

Presented To

CITY OF SCOTTSDALE

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PENTACORE
ARIZONA
Civil Engineering • Construction Administration
Land Surveying • Planning • ADA Consulting
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September 1998

A027.925

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1.0 PROJECT DESCRIPTION

The Hayden Road Stormdrain is part of the Pima Road drainage improvements associated with the Scottsdale Desert Greenbelt Project. Pentacore Arizona, as a subconsultant to Stantech Engineering, has been contracted to design the stormdrain system for the City of Scottsdale (City) and the Flood Control District of Maricopa County (FCD). This report describes the design approach, parameters and performance characteristics of the Hayden Road Stormdrain. The stormdrain serves as the principal outlet structure for the Pima Freeway Detention Basin located north of the Arizona Department of Transportation (ADOT) proposed Outer Loop Pima Freeway (Route 101). The stormdrain is approximately 6,100 feet in length with an alignment parallel to Hayden Road from the Pima Freeway Basin (Station 72+00) to the outlet discharge at the U.S. Bureau of Reclamation (USBR) regional retention facilities located at the Tournament Players Club Golf Course (TPC) near the southeast corner of the intersection of Hayden Road and Bell Road (Station 11+00). Stantech is responsible for the design of the stormdrain from the Pima Freeway Basin to the end of the ADOT freeway right-of-way (Station 63+00), approximately 900 linear feet. Pentacore is responsible for the design of the downstream portion of the stormdrain from the ADOT right-of-way to the outlet at the TPC, approximately 5,200 linear feet, and the outlet structure. Figure 1 depicts the overall horizontal alignment of the stormdrain and the site layout. Preliminary plan and profile construction drawings are provided in Appendix A.

1.1 Principal Design Criteria

Since the stormdrain serves as the principal outlet for the Pima Freeway Basin, the downstream design by Pentacore is greatly dependent upon the performance parameters established by Stantech for the basin. As such, Stantech has prescribed that the basin outlet perform under inlet control conditions which was used to establish the stage-storage-discharge relationship for the design of the basin. Using dual 108-inch diameter concrete culverts, Stantech calculated the peak discharge rate from the basin to be 2,150 cfs based on nomographs from the Federal Highway Administration (FHWA) [1]. The design of the stormdrain must therefore meet two principal criteria 1) convey a design discharge rate of 2,150 cfs, and 2) convey the design discharge rate under non-pressurized conditions at station 63+00 to ensure that inlet control conditions are maintained at the freeway basin outlet.

1.2 Other Design Criteria

A number of alternative materials have been considered during the course of design for the Hayden Road Stormdrain in an effort to minimize the overall cost of the system. Materials which have been considered include reinforced concrete pipe (RCP), non-reinforced, cast-in-place concrete pipe (CIP) and cast-in-place concrete arch structures. Other materials may prove to be feasible alternatives, but are beyond the scope for this study. Each of the materials considered have both advantages and disadvantages associated with their use. RCP offers a proven history of structural performance, but at a substantial cost increase to the other materials. The structural performance of CIP, while not as efficient as RCP, has been documented by others for this project to be suitable for stormdrain applications given several limiting design constraints. CIP still represents a potentially significant cost savings to RCP. CIP concrete arches offer improved structural characteristics over CIP and a potential cost discount compared to RCP, but CIP arch

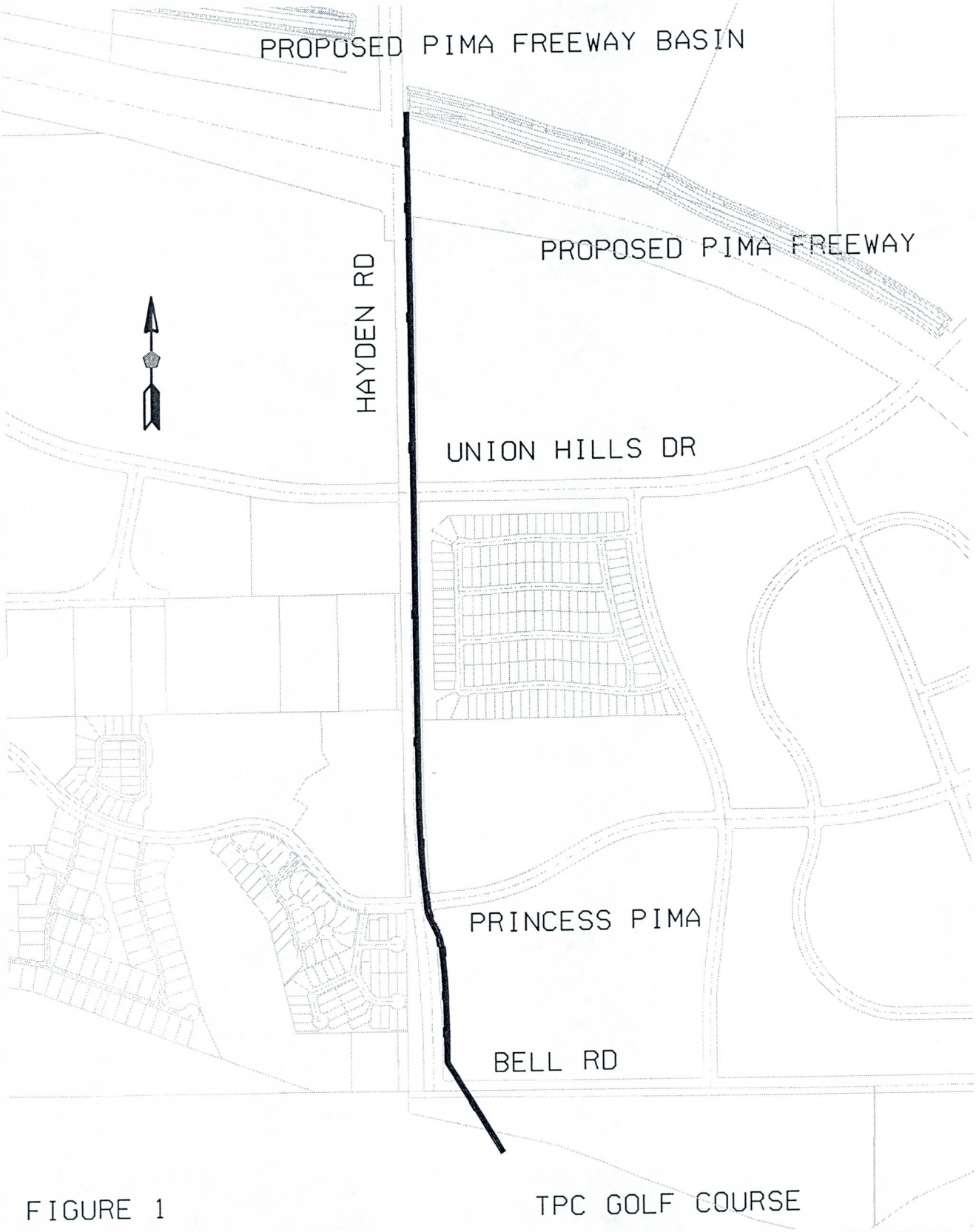

PROPOSED PIMA FREEWAY BASIN
PROPOSED PIMA FREEWAY
HAYDEN RD
UNION HILLS DR
PRINCESS PIMA
BELL RD
TPC GOLF COURSE

FIGURE 1

is a fairly recent construction material alternative and has a relatively limited performance history compared to RCP and CIP. Given these conditions, Pentacore was directed by the City to design a composite stormdrain system consisting of CIP and RCP, where CIP is used to the greatest extent possible, and where RCP is used whenever field and hydraulic conditions prohibit the use of CIP.

The design constraints which exist for the use of CIP have been established based on design specifications described by the American Concrete Institute, hydraulic studies conducted by other experts for the Pima Road drainage system and general conversations with reviewers of this project throughout the preliminary design phase. A design standard established by ACI indicates that the static pressure within CIP should not exceed 15 feet above the springline of the pipe. Similarly, a hydraulic study performed by others to analyze transient flow conditions within a stormdrain indicates that certain circumstances of transient flow could result in damage to CIP pipe. Therefore, CIP is used within the Hayden Road Stormdrain system where the hydraulic grade line does not exceed 15 feet above the springline of the pipe. Additionally, open-grated, large diameter (5-foot) manholes are provided at a spacing along the course of the stormdrain where CIP is used so that the maximum energy grade difference between manholes is less than 15 feet of head. The large diameter manholes will provide a pressure release throughout the stormdrain system to alleviate the adverse conditions that may occur as a result of transient flow as described within the hydraulic studies conducted by others.

1.3 Other Design Issues

The advantages of cast-in-place materials rely greatly upon the field conditions for construction of the culverts and the insitu soil characteristics. A geotechnical study conducted by others for the Pima Road drainage system indicates that while not prohibitive, the field conditions may be less than optimal for the construction of CIP. The soils tend to be moderately cemented at the depths proposed for the stormdrain which increases the difficulty of excavation. Furthermore, the soils report also indicates that pockets of non-cohesive soil material may be encountered which would affect the trench stability associated with CIP installation. These conditions may impact the economic advantages of cast-in-place materials. Likewise, these soil issues may impact the suitability of use of other alternative materials, as well.

There has been an expressed concern during preliminary design meetings regarding the tolerability of CIP with respect to high flow velocities. There are a number of design standards which indicate that CIP is permissible for flow velocities up to 40 fps.[2] On the basis of velocity, CIP has been prescribed wherever the peak flow velocity is less than 40 fps. If there is concern with the use of CIP for high velocity areas, concrete strength and aggregate hardness may be increased to alleviate some concern.

As discussed during preliminary design meetings, it is recommended that potential Contractors for the construction of the project satisfy for themselves the suitability of alternative materials for the construction of the stormdrain given the field conditions of the site and the hydraulic parameters established for this design. Extensive investigation for the suitability of alternative pipe materials exceeded the scope of this project and was not considered beyond the extent described herein.

2.0 ALIGNMENT AND PROFILE

The alignment for the stormdrain is shown on the plan and profile drawings in Appendix A. The alignment has been established to minimize impacts to existing facilities and utilities located in Hayden Road and at the TPC. The alignment control for this project is based on City of Scottsdale datum. Three benchmarks in the project vicinity are used as the basis for horizontal control: 1) a COS aluminum cap at the intersection of Hayden and Bell Roads (N 960454.311, E 702638.803); 2) a GLO brass cap at the east ¼ of section 35, T4N, R4E (N 963263.096, E 702640.828); and 3) a COS brass cap at the north corner of section 2, T3N, R4E (N 960421.063, E 705279.746). The vertical control benchmark for the project is the COS aluminum brass cap (El. 1542.865) located at the intersection of Hayden and Bell Roads.

Utilities have been located using the City's utility quarter section maps, design plans for other projects in the area, and field review. In several cases, there is conflicting information between the City's data and the design drawings with regard to the description and location of the existing utilities. The plan and profile drawings represent the best estimate for the location of the existing utilities.

2.1 Horizontal Alignment

The upstream horizontal alignment for the stormdrain is governed by the location of the Pima Freeway Basin Outlet designed by Stantech. Downstream, the City directed Pentacore to locate the outlet as near to Hayden Road as possible while minimizing the impact to existing facilities. The remainder of the stormdrain alignment is routed within the right-of-way for Hayden Road where the alignment shown on the plans was selected to route the 30-foot trench width (at culvert springline) to the outlet while minimizing the impact to existing facilities. While the horizontal alignment has been selected to minimize impacts to existing utilities, the top width of the trench will be considerably wider than 30 feet without shoring due to the depth of the stormdrain. This will impact existing utilities and many will need to be protected in place during construction.

Bends in the alignment to avoid conflicts were designed with large radii so that RCP could be substituted throughout the system without altering the alignment. If RCP is the selected pipe material, the stormdrain can be constructed to the alignment shown on the plans within the allowable tolerance for pipe joint deflection. Gradual bends also have minimal impact to the hydraulic performance of the stormdrain.

2.2 Vertical Alignment

The vertical alignment of the stormdrain was selected to avoid utility conflicts, ensure inlet control parameters within the upstream portion of the stormdrain, and to minimize the depth of the stormdrain for cost efficiency. The vertical alignment begins at station 63+00 at an invert elevation of 1583.15 which was established by Stantech. The outlet into the existing channel at the TPC has an invert elevation of 1521.0. The remainder of the stormdrain is designed to meet the project goals described while providing a minimum 4-foot cover below existing grade.

A 66-inch diameter water main located at the intersection of Hayden Road and Union Hills Drive presents the most significant impact to the profile alignment of the stormdrain. The optimal crossing of the water line was determined to be at Union Hills Drive. While the depth of

excavation is substantial, approximately 30 feet, this depth of excavation would be approximately the same regardless of the crossing point chosen. The selected alignment was chosen because it avoids other potential utility conflicts. The stormdrain is sloped at a 4-percent grade to dip below the 66-inch water line. The steep slope is used to minimize the amount of excavation and reduce project costs. Once past the water line, the stormdrain is sloped at a 0.75-percent grade to return to a 4-foot cover depth.

3.0 HYDRAULICS

The hydraulic conditions for the Hayden Road Stormdrain are described herein for the design flowrate, 2,150 cfs. Plan and profile drawings provided in Appendix A display the hydraulic grade line (HGL) and the energy grade line (EGL) for the design discharge flow rate. The hydraulic characteristics for the stormdrain were obtained from a model using the program StormCAD (Version 1.0) which is a commercially developed program by Haestad for stormdrain analysis. The results of the StormCAD model were verified with hand calculations for backwater analysis using a spreadsheet to facilitate the calculations.

3.1 Roughness Coefficients and Alternative Materials

The hydraulic analysis was conducted using a consistent value of 0.015 for the Manning's roughness n-value. This value was used to analyze both RCP and CIP pipe and is based on the assumption that the flow is clean and relatively free of sediment. The use of a consistent roughness value permits the interchangeable use of the two pipe materials throughout the stormdrain system without affecting the hydraulic characteristics of the system.

Typical roughness values for RCP range between 0.011 and 0.015 as documented in the design manual for FCD[3]. The value of 0.015 represents a conservative approach in terms of sizing RCP for adequate conveyance capacity.

The Manning's roughness value for CIP typically ranges between 0.012 and 0.018, although not described by either design manual for the City[4] or FCD. The range in value for CIP is much greater than that for RCP due to the field construction procedure of the pipe and the degree of irregularity that is associated with this material. The value of 0.012 is obtained from the Lynch Manual[5] construction handbook for CIP while 0.018 is describe by other standard hydraulic references. A roughness value of 0.015 is considered to be reasonable for clean flow to account for pipe degradation as well as surface and cross-sectional irregularities.

3.2 Headloss Coefficients

The predominant cause of headloss within the stormdrain system is expected to occur at bends in the system. Loss coefficients were estimated using standard references for pipe losses[1,6,7]. A table of standard loss coefficients is provided in Appendix B. An expansion loss coefficient of 0.16 is used at station 22+82 where the stormdrain expands from a dual 108-inch diameter culvert section to a dual 120-inch diameter culvert section. An exit loss coefficient of 1.0 is used for the discharge outlet. A loss coefficient of 0.08 is used for gradual, pipe deflection bend losses that occur regularly throughout the stormdrain system. Headlosses at manholes were considered to be insignificant because the manholes, located at the crown of the pipe, do not significantly

impede the flow within the large diameter pipe. The system has no other facilities that are believed to cause a significant headloss.

An entrance headloss was not considered because this design is developed for the downstream section of the entire Hayden Road Stormdrain. At the upstream beginning for this design, station 63+00, normal flow conditions were assumed for the analysis as the flow is already fully integrated into the stormdrain system at this location.

3.3 Hydraulic parameters

As previously stated, the hydraulic parameters are established for a design flow rate of 2,150 cfs in a dual culvert stormdrain system. The design assumes that the flow is evenly distributed between the two culverts, or that each culvert conveys a design flow rate of 1,075 cfs. Stantech has designed the upstream portion of the stormdrain such that dual 108-inch diameter RCP culverts, at a slope of 0.0095 feet/feet convey the design discharge to station 63+00. At station 63+00, the culvert invert elevation is 1583.15. For normal flow conditions, the flow is supercritical where the flow depth is 7.54 feet resulting in a HGL elevation of 1590.69 and an EGL elevation of 1596.23.

The hydraulic performance of the Hayden Road Stormdrain was analyzed for two downstream conditions; with downstream impoundment and without downstream impoundment. A condition with downstream impoundment may occur because the stormdrain is designed to outlet into the USBR retention facility which was designed to have a 100-year water surface elevation of 1531.0. This elevation coincides with the top of the culvert and will create a condition of impoundment. It is likely, however, that the timing between the high water elevation in the USBR and the peak discharge rate from the stormdrain will not coincide, in which case, there will be no downstream impoundment. Critical depth is used at the stormdrain outlet to evaluate the hydraulic conditions for the stormdrain without downstream impoundment.

3.4 Hydraulic Modeling Results and System Characteristics

The hydraulic analysis for the Hayden Road Stormdrain was conducted using the StormCAD program as well as hand calculations based on a backwater analysis. The results from both approaches are presented in Appendix B. The hand calculations are considered to be more accurate than the results of the StormCAD model because of limitations with the program that were confirmed with Haestad. The StormCAD program is not capable of handling transitions between supercritical and subcritical flow regimes. To account for hydraulic jumps that may occur in the stormdrain system, the StormCAD program estimates the upstream water surface elevation to be at the critical flow depth. The backwater analysis is interrupted at this occurrence and the flow depth is re-established to the critical flow depth where the program resumes the backwater analysis for the next reach of calculations. The error will continue to propagate through the system for the remainder of the calculations. The StormCAD modeling approach affects the analysis of the Hayden Road Stormdrain because the upper reaches of the stormdrain are established with supercritical slopes to ensure inlet control conditions persist at the Pima Freeway Basin.

Secondly, the StormCAD program is not capable of accurately accounting for minor bend losses that occur regularly throughout the Hayden Road stormdrain system. The StormCAD program is only capable of handling minor head losses due to bends at junctions, but that is not representative of this system. Rather than junctions, bends occur gradually through a length of the culverts, and therefore, the headloss should be more appropriately applied to the energy slope for that length. Albeit, the differences which arise because of this circumstance and the resulting impacts to the calculated EGL are slight.

The hand calculations establish the upstream flow depth by balancing the energy using the supercritical flow regime. The supercritical flow depth more accurately models the upstream flow depth for these unstable occurrences. The results from the hand calculations can also be used to estimate the energy that is lost due to the hydraulic jump. For these reasons, the hand calculations are believed to be a more accurate account of the stormdrain performance where the HGL and EGL results from this analysis are shown on the plan and profile sheets.

A summary table of hydraulic data is provided to compare the results between the StormCAD model and hand calculations. The results from the StormCAD model overestimate the elevation of the EGL in the upstream reaches of the stormdrain because the program falsely assumes critical depth for a supercritical flow regime. The results from the hand calculation for the condition with downstream impoundment consistently yields the greatest EGL elevation throughout the stormdrain except in the upstream reaches where supercritical flow persists and the StormCAD model estimates a greater EGL elevation. The effect of downstream impoundment to the hydraulic characteristics of the stormdrain is minimal where the EGL between the two conditions, with and without downstream impoundment, is less than 1-foot throughout the system. The results from the hand calculation for the condition with downstream impoundment represents the conservative condition for the stormdrain.

4.0 SUMMARY AND COMMENTS

This 30-percent report and accompanying plans represent a preliminary design condition based on the best available information at this time. The hydraulic parameters and layout alignment of the Hayden Road Stormdrain is subject to change, particularly given that the Pima Freeway Basin is currently under design. Changes to the basin design may have an impact to the stormdrain depending upon the nature of the revisions.

5.0

REFERENCES

[1] Federal Highway Administration, "Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5", 1985.
[2] Arizona Department of Transportation, "Pipe Selection Guidelines and Procedures", 1996.
[3] Flood Control District of Maricopa County, "Drainage Design Manual for Maricopa County, Volume II Hydraulics", 1992.
[4] City of Scottsdale, Arizona, "Design Standards and Policies Manual", 1998.
[5] Tremont Equipment Company, "Lynch Manual, Cast-in-place Concrete Pipe Process", 1990.
[6] Roberson, J.A., Crowe, C. T., "Engineering Fluid Mechanics", 5ed, 1993.
[7] Linsley, R.K., Franzini, J.B., Freyberg, D.L and Tchobanoglous, G. T., "Water-Resources Engineering", 4ed, 1992.

Appendix A

30% Preliminary Design Plans

CITY OF SCOTTSDALE
PUBLIC IMPROVEMENTS

COUNCIL

SAM KATHRYN CAMPANA, MAYOR
CYNTHIA LUKAS
GEORGE ZRAKET
MARY MANROSS
ROBERT C. PETTYCREW
DENNIS E. ROBBINS
RICHARD THOMAS

CITY MANAGER

RICHARD A. BOWERS

CITY ATTORNEY

FREDDA BISMAN

CITY CLERK

SONIA ROBERTSON

"AS-BUILT" CERTIFICATION

I HEREBY CERTIFY THAT THE "AS-BUILT" IMPROVEMENTS AS SHOWN HEREON ARE LOCATED AS NOTED, AND THE LOCATIONS ARE CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

REGISTERED LAND SURVEYOR _____ DATE _____

CITY OF SCOTTSDALE

REVIEWED AND RECOMMENDED APPROVAL BY:

FIRE DEPT.		GRADING & DRAINAGE	
LANDSCAPE & PLANNING		WATER & SEWER	
TRAFFIC		PAVING	

APPROVED BY:

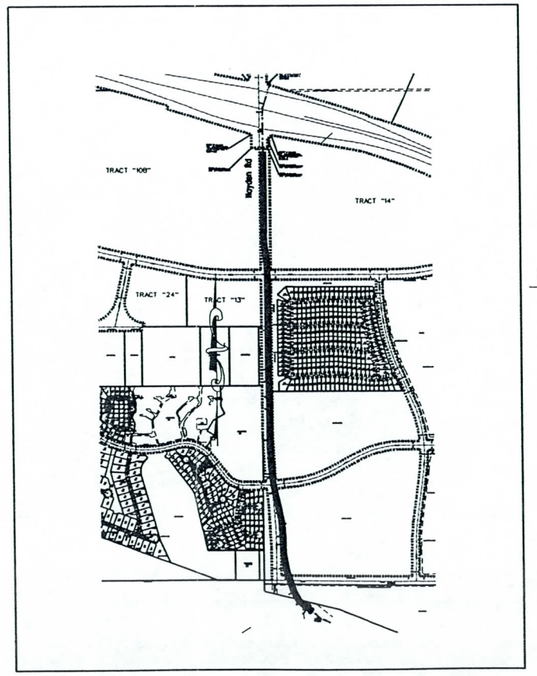
PROJECT REVIEW MANAGER _____ DATE _____

Two working days before you dig
CALL FOR THE BLUE STAKES
263-1100
Blue Stake Center
CALL COLLECT

ENGINEER

SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORMDRAIN

SITE MAP AND AREA OF WORK



Vicinity Map
N.T.S.

Sheet Index

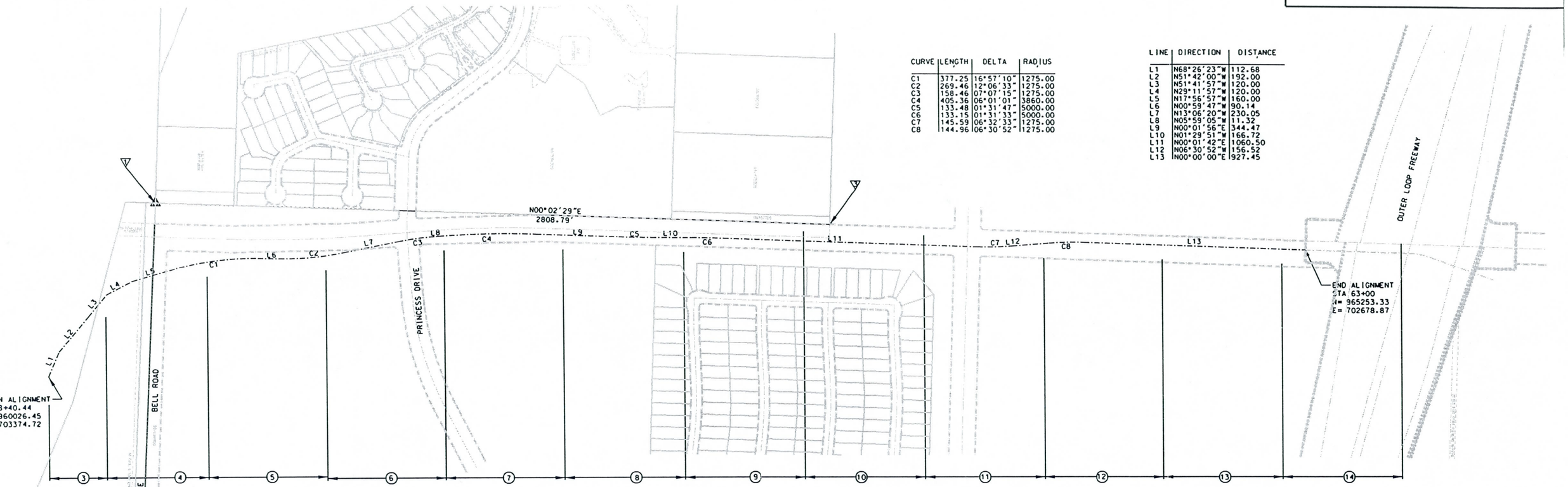
Sht. No.	Description
1 -	COVER SHEET
2 -	GEOMETRIC CONTROL
3 - 14	PLAN AND PROFILE
15 -	DETAILS

HAYDEN ROAD STORMDRAIN
PROJECT NO.

PENTACORE
ARIZONA
Civil Engineering · Construction Administration
Land Surveying · Planning · ADA Consulting
2255 No. 44th St., SUITE 255 Phoenix, AZ 85008
TELEPHONE (602) 681-9272 FAX (602) 681-9339

CURVE	LENGTH	DELTA	RADIUS
C1	377.25	16°57'10"	1275.00
C2	269.46	12°06'33"	1275.00
C3	158.46	07°07'15"	1275.00
C4	405.36	06°01'01"	3860.00
C5	133.48	01°31'47"	5000.00
C6	133.15	01°31'33"	5000.00
C7	145.59	06°32'33"	1275.00
C8	144.96	06°30'52"	1275.00

LINE	DIRECTION	DISTANCE
L1	N68°26'23"W	112.68
L2	N51°42'00"W	192.00
L3	N51°41'57"W	120.00
L4	N29°11'57"W	120.00
L5	N17°56'57"W	160.00
L6	N00°59'47"W	90.14
L7	N13°06'20"W	230.05
L8	N05°59'05"W	11.32
L9	N00°01'56"E	344.47
L10	N01°29'51"W	166.72
L11	N00°01'42"E	1060.50
L12	N06°30'52"W	156.52
L13	N00°00'00"E	927.45



PROJECT BENCH MARKS:

HORIZONTAL AND VERTICAL CONTROL POINT
NE COR SEC 2 T3N R4E
COS ALUMINUM CAP IN HH
N = 960454.311
E = 702638.803
ELEV = 1542.865

HORIZONTAL CONTROL POINT
N COR SEC 1 T3N R4E
COS BC FLUSH IN MEDIAN
N = 960421.063
E = 705279.746

HORIZONTAL CONTROL POINT
E¼ SEC 35 T4N R4E
GLO BC 1914 FLUSH IN DIRT UP 0.1'
N = 963263.096
E = 702640.828

NOTES:

1. ALL COORDINATES ARE GROUND COORDINATES BASED ON MONUMENT DATA AS PROVIDED BY THE CITY OF SCOTTSDALE.
2. ALL MONUMENTATION DISTURBED DURING CONSTRUCTION WILL BE RE-ESTABLISHED BY THE CONTRACTOR IN ACCORDANCE WITH MAG REQUIREMENTS.

LEGEND:

R/W - RIGHT-OF-WAY
RW - RAW WATER
FO - FIBER OPTIC
W - WATER
S - SEWER
EC - ELECTRICAL
TV - TELEVISION
SD - STORM DRAIN
G - GAS

CITY OF SCOTTSDALE

GENERAL CONSTRUCTION NOTES FOR PUBLIC WORKS CONSTRUCTION

1. ALL CONSTRUCTION IN THE PUBLIC RIGHTS-OF-WAY OR IN EASEMENTS GRANTED FOR PUBLIC USE MUST CONFORM TO THE LATEST MARICOPA ASSOCIATION OF GOVERNMENTS (MAG) UNIFORM STANDARD SPECIFICATIONS AND UNIFORM STANDARD DETAILS FOR PUBLIC WORKS CONSTRUCTION AS AMENDED BY THE LATEST VERSION OF THE CITY OF SCOTTSDALE (COS) SUPPLEMENTAL STANDARD SPECIFICATIONS AND SUPPLEMENTAL STANDARD DETAILS. IF THERE IS A CONFLICT, THE LATTER SHALL GOVERN.

2. THE ENGINEERING DESIGNS ON THESE PLANS ARE ONLY APPROVED BY THE CITY IN SCOPE AND NOT IN DETAIL. IF CONSTRUCTION QUANTITIES ARE SHOWN ON THESE PLANS, THEY ARE NOT VERIFIED BY THE CITY.

3. APPROVAL OF PLANS ARE VALID FOR (6) MONTHS. IF AN ENCROACHMENT PERMIT FOR THE CONSTRUCTION HAS NOT BEEN ISSUED WITHIN SIX MONTHS, THE PLANS SHALL BE RESUBMITTED TO THE CITY FOR RE-APPROVAL.

4. A CITY CAPITAL PROJECT'S INSPECTOR WILL INSPECT ALL WORK INDICATED BY THE PLANS. INSPECTION OF WORK FOR COMPLIANCE WITH UNIFORM/ NATIONAL CODES, AS MANY AS INDICATED ON THE PLANS, WILL BE DONE BY A CITY PUBLIC WORKS INSPECTOR. NOTIFY INSPECTION SERVICES 24 HOURS PRIOR TO STARTING OF CONSTRUCTION (TELEPHONE 391-5750).

5. WHENEVER EXCAVATION IS TO BE DONE, CALL THE "BLUE STAKE CENTER", 263-1100, TWO WORKING DAYS BEFORE EXCAVATION IS TO BEGIN. THE CENTER WILL SEE THAT THE LOCATION OF THE UNDERGROUND UTILITY LINES IS IDENTIFIED FOR THE PROJECT. CALL "COLLECT" IF NECESSARY.

6. ENCROACHMENT PERMITS ARE REQUIRED FOR ALL WORK IN PUBLIC RIGHTS-OF-WAY AND EASEMENTS GRANTED FOR PUBLIC PURPOSES. AN ENCROACHMENT PERMIT WILL BE ISSUED BY THE CITY. COPIES OF ALL PERMITS SHALL BE RETAINED ON SITE AND SHALL BE AVAILABLE FOR INSPECTION AT ALL TIMES. FAILURE TO PRODUCE THE REQUIRED PERMITS WILL RESULT IN IMMEDIATE WORK STOPPAGE UNTIL THE PROPER PERMIT DOCUMENTATION IS OBTAINED.

7. ALL EXCAVATION AND GRADING WHICH IS NOT IN THE PUBLIC RIGHTS-OF-WAY OR NOT IN EASEMENTS GRANTED FOR PUBLIC USE MUST CONFORM TO CHAPTER 70, EXCAVATION AND GRADING, OF THE LATEST EDITION OF THE UNIFORM BUILDING CODE PREPARED BY THE INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS. A PERMIT FOR THIS GRADING MUST BE SECURED BY THE CITY.

8. EXISTING UTILITIES SHOWN ON THESE PLANS ARE BASED ON INFORMATION OBTAINED BY OTHERS. THE CONTRACTOR SHALL DETERMINE THE EXACT LOCATION AND/OR ELEVATIONS OF EXISTING UTILITIES WHICH PERTAIN TO AND MAY AFFECT THE CONSTRUCTION.

200 0 200 400

NOT FOR CONSTRUCTION

DATE	REVISION	BY

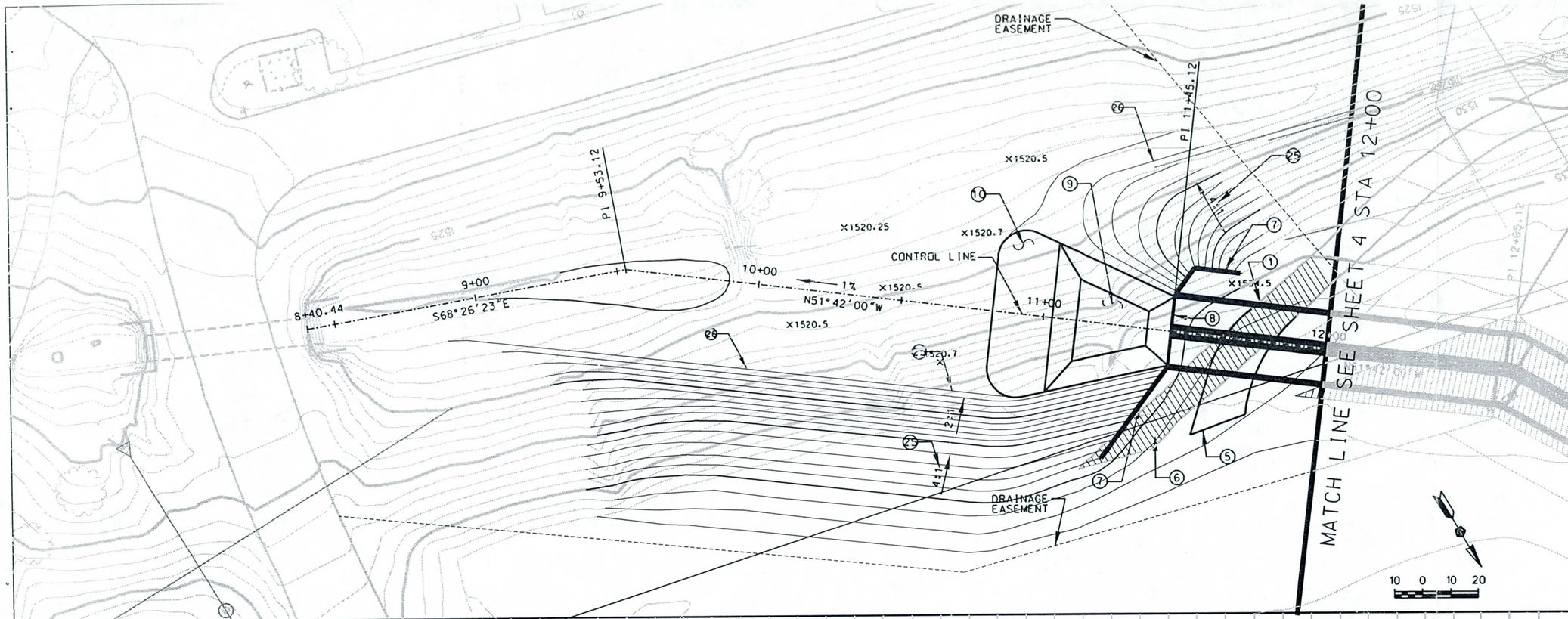
ENGINEER

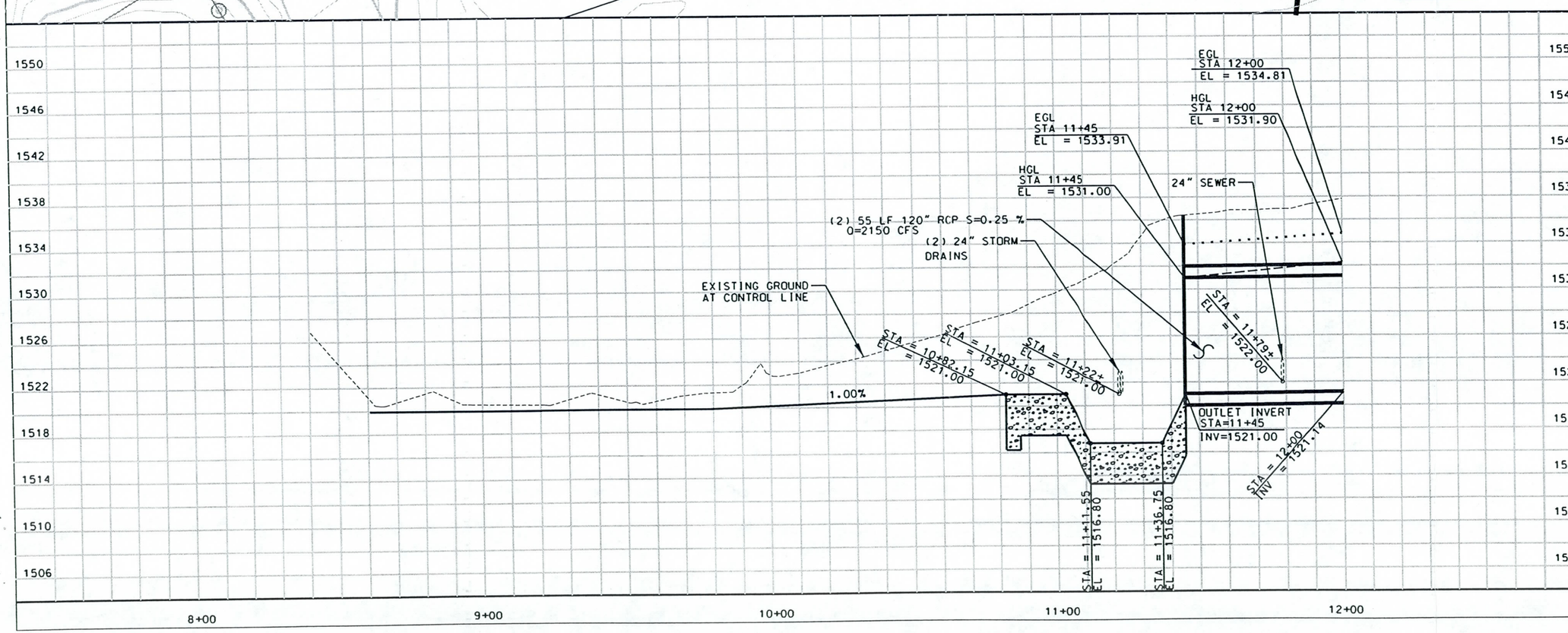
CITY OF SCOTTSDALE ARIZONA

TRANSPORTATION DEPARTMENT
TRANSPORTATION PLANNING
3939 CIVIC CENTER BLVD.
SCOTTSDALE, ARIZONA 8525

PROJECT TITLE DESERT GREENBELT PIMA ROAD 3 BASINS
GEOMETRIC CONTROL / GENERAL NOTES / LEGEND

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 2
HORIZ. 1"=200'	TJC	9/18/98		
VERT.	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	2 OF 15





PENTACORE ARIZONA
Civil Engineering · Construction Administration
Land Surveying · Planning · ADA Consulting
2255 No. 44th St., SUITE 255 Phoenix, AZ 85008
TELEPHONE (602) 681-9272 FAX (602) 681-9339

REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

1. INSTALL (2) 120" RCP'S (SEE DETAIL B - SHEET 15)
5. REMOVE AND REPLACE EXISTING CONCRETE SIDEWALK AS SHOWN
6. REMOVE EXISTING PATH WITHIN THE LIMITS SHOWN
7. CONSTRUCT REINFORCED CONCRETE WING WALL. SEE DETAIL SHEET 15
8. REINFORCED CONCRETE HEADWALL SEE DETAIL SHEET 15
9. RIPRAP BASIN ENERGY DISSIPATOR SEE DETAIL SHEET 15
10. CONSTRUCT ENERGY DISSIPATOR APRON PER DETAIL SHEET 15
25. REGRADE SLOPE AS SHOWN
26. RESEED DISTURBED SLOPE WITH VEGETATIVE SEED MIX

CALL TWO WORKING DAYS BEFORE YOU DIG
263-1100
1-800-STAKE-IT
(OUTSIDE MARICOPA COUNTY)

NOT FOR CONSTRUCTION

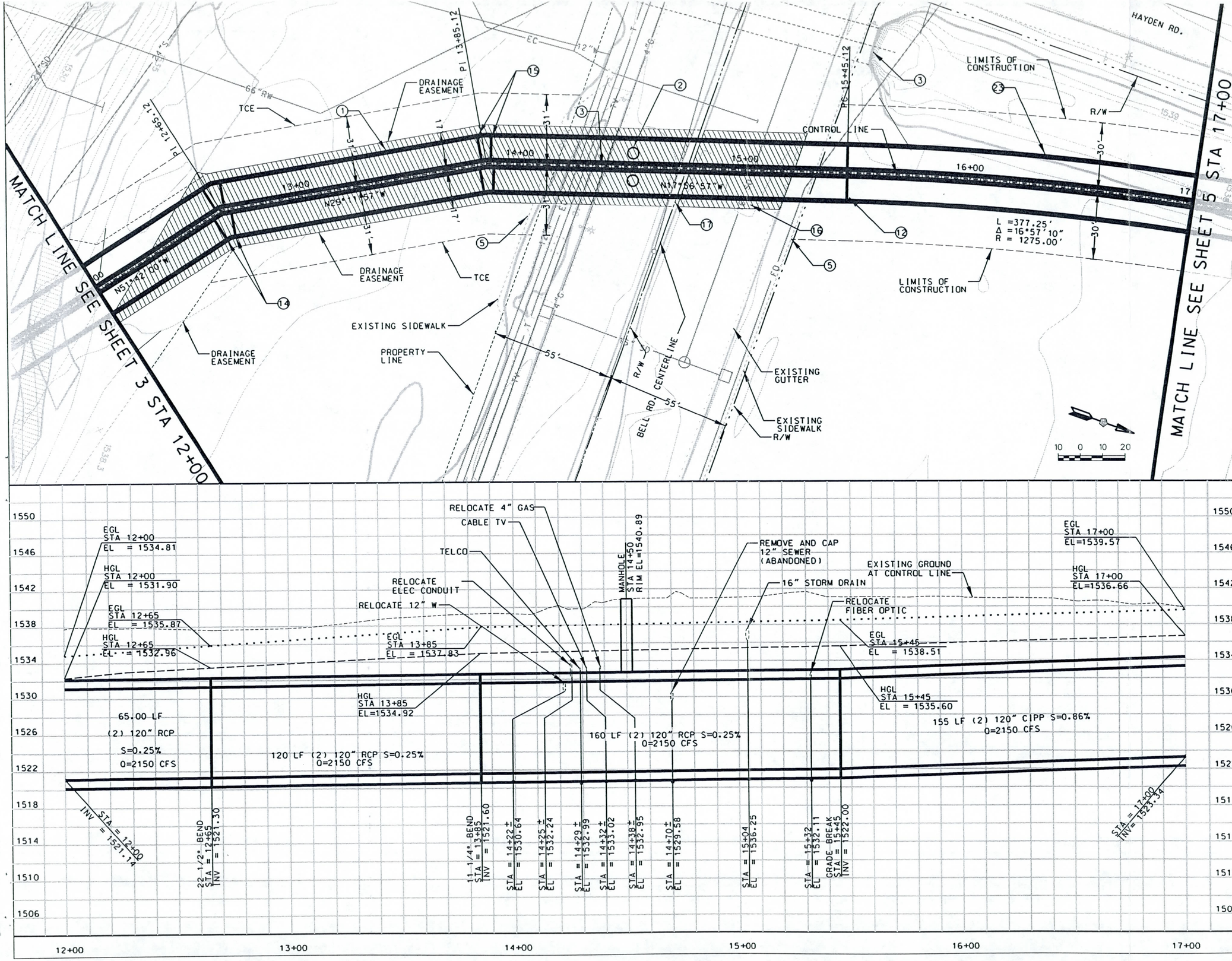
DATE	REVISION	BY

ENGINEER

TRANSPORTATION DEPARTMENT
TRANSPORTATION PLANNING
3939 CIVIC CENTER BLVD.
SCOTTSDALE, ARIZONA 852

PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ 1"=20'	TJC	9/18/98		3
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5009.0001	3 OF 1



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

1. INSTALL (2) 120" RCP'S (SEE DETAIL B - SHEET 15)
2. INSTALL (2) MANHOLES PER MAG STD DTL 521
3. PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT AS OTHERWISE NOTED
5. REMOVE AND REPLACE EXISTING CONCRETE SIDEWALK
12. CONSTRUCT CONCRETE PIPE COLLAR PER MAD STD DTL 505
14. INSTALL (2) 120" RCP 22½° BENDS
15. INSTALL (2) 120" RCP 11¼° BENDS
16. REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING
17. REMOVE AND REPLACE EXISTING CONCRETE MEDIAN. MATCH EXISTING
23. INSTALL (2) 120" CIPP (SEE DETAIL - A SHEET 15)

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DATE	REVISION	BY

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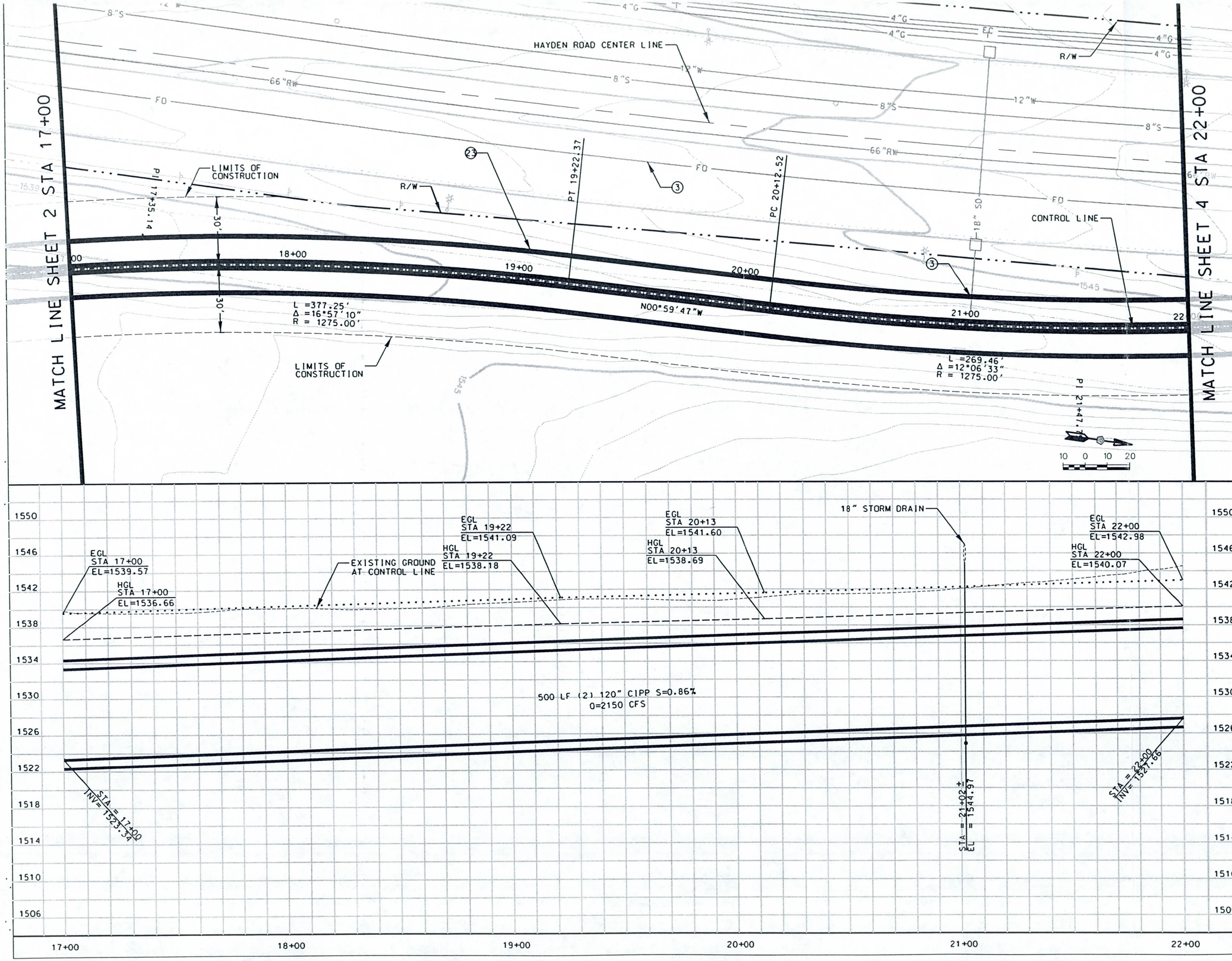
3939 CIVIC CENTER BLVD.
SCOTTSDALE, ARIZONA 8525

PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 4
HORIZ. 1"=20' VERT. 1"=5'	TJC	9/18/98		
	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	4 OF 15



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REMOVAL NOTES:

Description	Unit	Quan.

CONSTRUCTION NOTES:

(3) PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT OTHERWISE NOTED

(23) INSTALL (2) 120" CIPP (SEE DETAIL A - SHEET 15)

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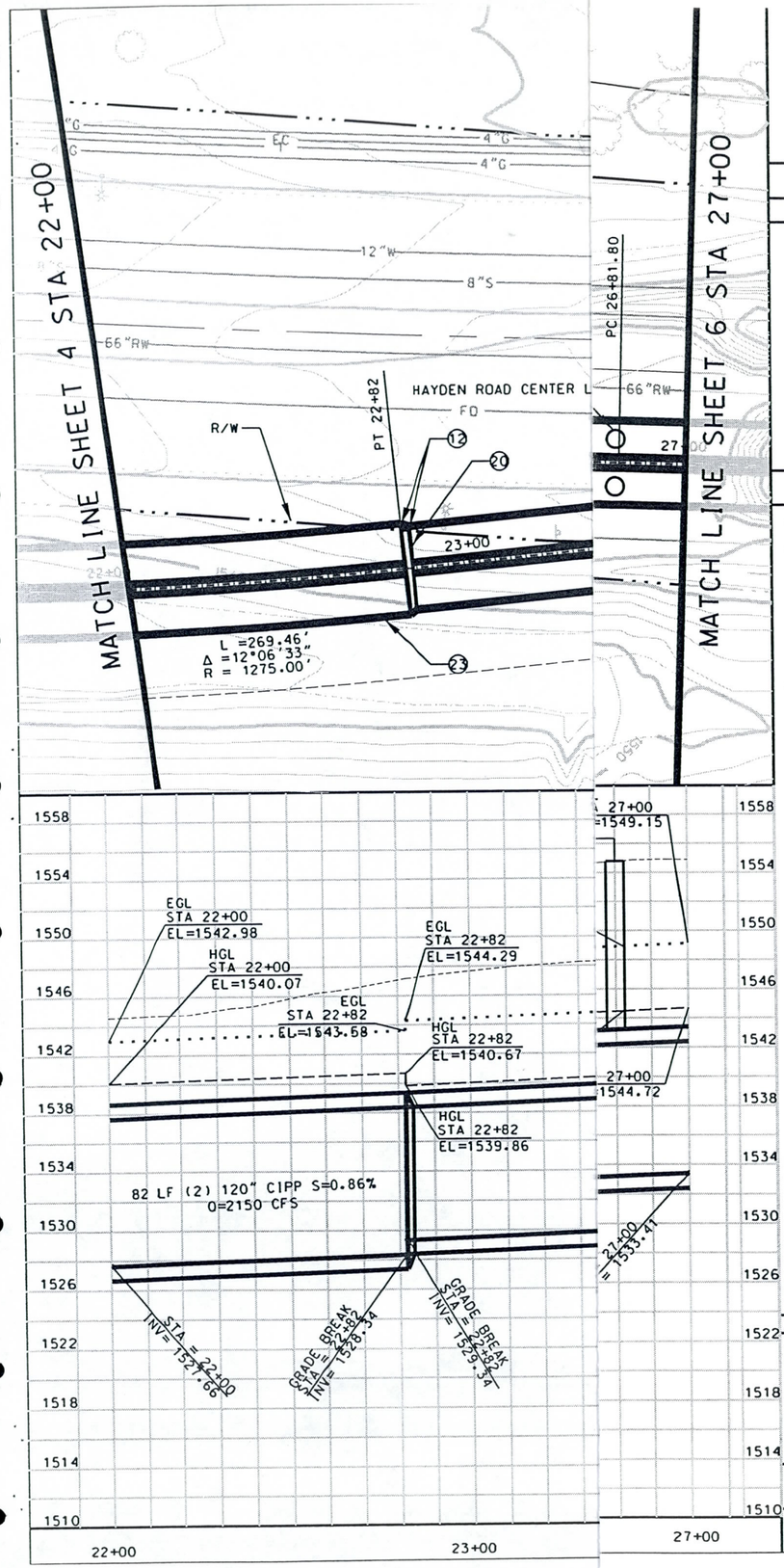
PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ. 1"=20'	TJC	9/18/98		5
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	5 OF 15



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

② INSTALL (2) MANHOLES PER MAG STD DTL 521

③ PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT OTHERWISE NOTED

⑫ CONSTRUCT CONCRETE PIPE COLLAR AS PER DETAIL "C" ON PAGE 15

⑯ REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING

⑳ INSTALL 108" x 120" CIPP TRANSITION

㉑ INSLALL (2) 108" CIPP (SEE DETAIL - A SHEET 15)

㉓ INSTALL (2) 120" RCP'S (SEE DETAIL A - SHEET 15)

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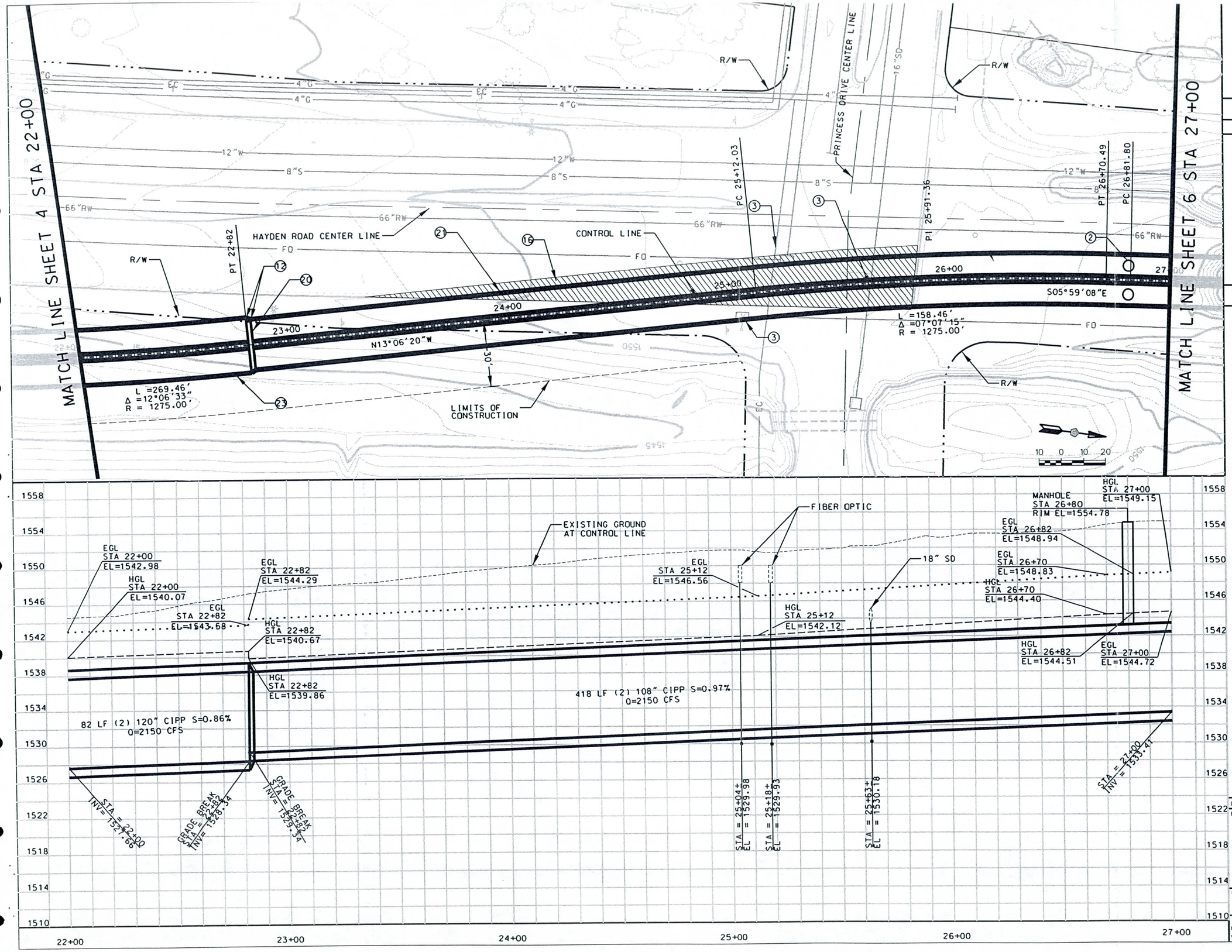
SCOTTSDALE, ARIZONA 8525

PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 6
HORIZ 1" =20'	TJC	9/18/98		
VERT. 1" =5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	6 OF 15



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

② INSTALL (2) MANHOLES PER MAG STD DTL 521

③ PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT OTHERWISE NOTED

⑫ CONSTRUCT CONCRETE PIPE COLLAR AS PER DETAIL "C" ON PAGE 15

⑯ REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING

⑳ INSTALL 108" x 120" CIPP TRANSITION

㉑ INSLALL (2) 108" CIPP (SEE DETAIL - A SHEET 15)

㉓ INSTALL (2) 120" RCP'S (SEE DETAIL A - SHEET 15)

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DATE	REVISION	BY

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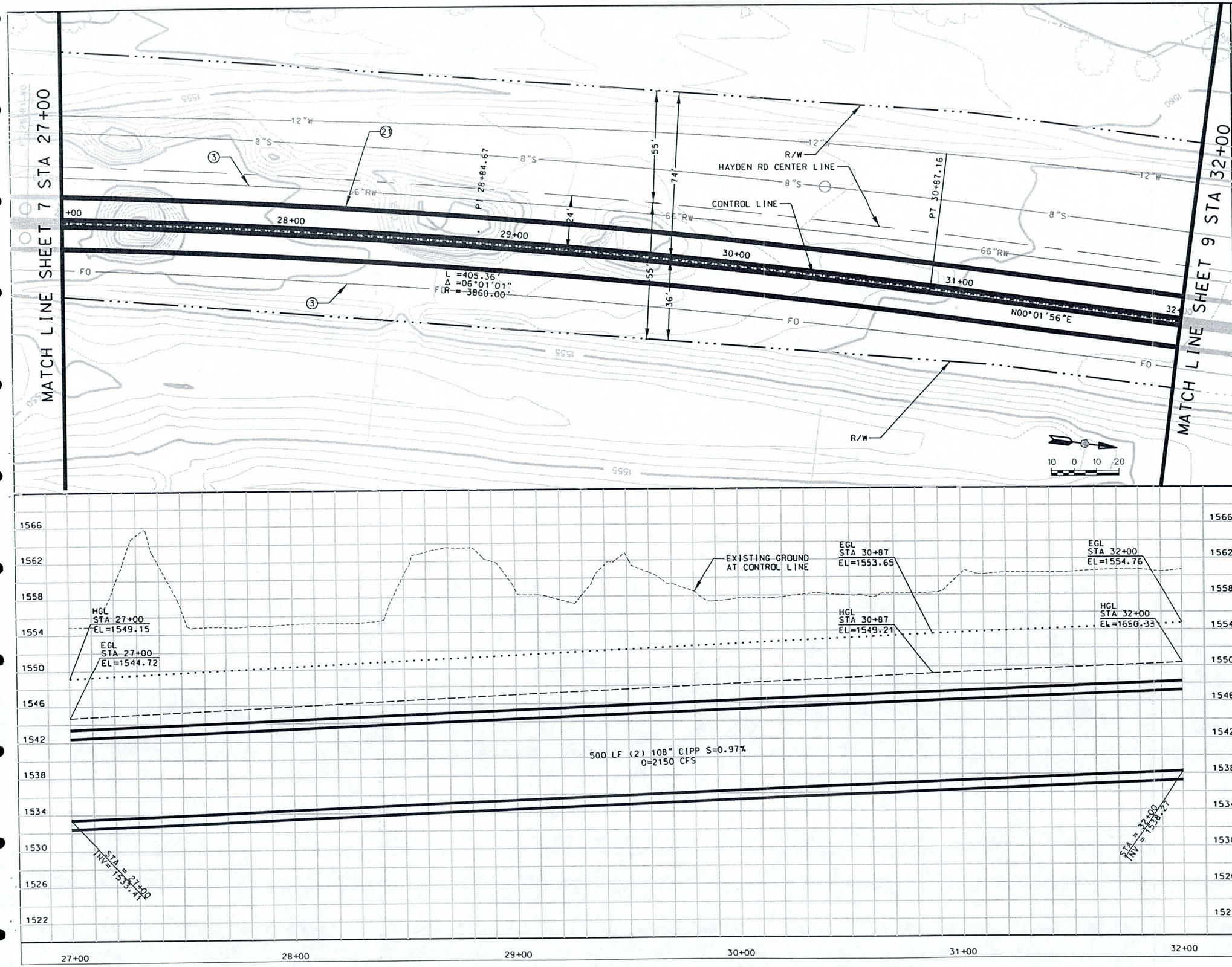
SCOTTSDALE, ARIZONA 8525

PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 6
HORIZ 1"=20'	TJC	9/18/98		
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	6 OF 15



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REMOVAL NOTES:

Description	Unit	Quan.

CONSTRUCTION NOTES:

(3) PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT AS OTHERWISE NOTED

(21) INSTALL (2) 108" CIPP (SEE DETAIL A - SHEET 15)

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DATE	REVISION	BY

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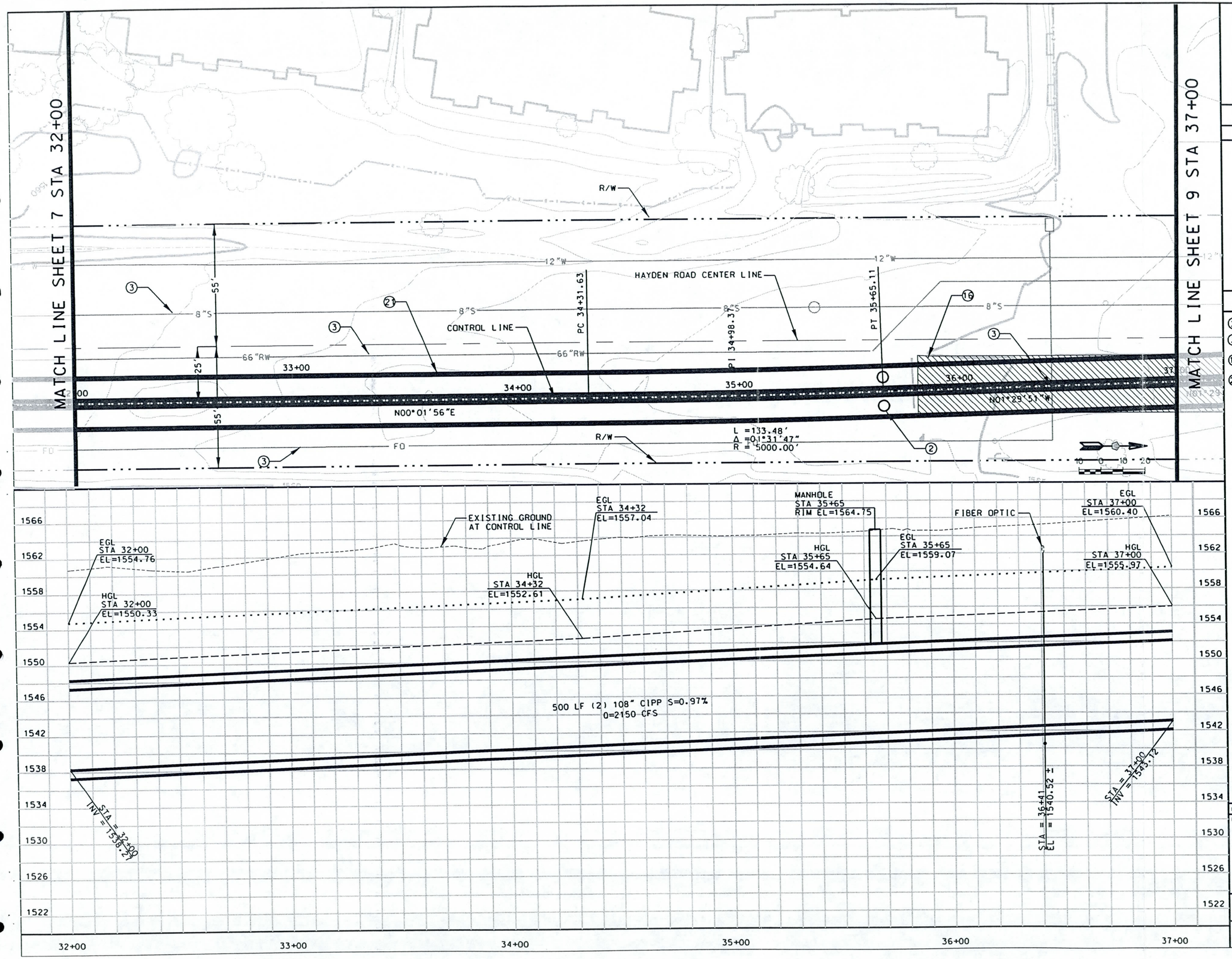
PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 7
HORIZ. 1"=20'	TJC	9/18/98		
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	7 OF 15



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REMOVAL NOTES:

Description	Unit	Quan.

CONSTRUCTION NOTES:

2. INSTALL (2) MANHOLES PER MAG STD DTL 521
3. PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT AS OTHERWISE NOTED
16. REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING
21. INSTALL (2) 108" CIPP (SEE DETAIL - A SHEET 15)

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DATE	REVISION	BY

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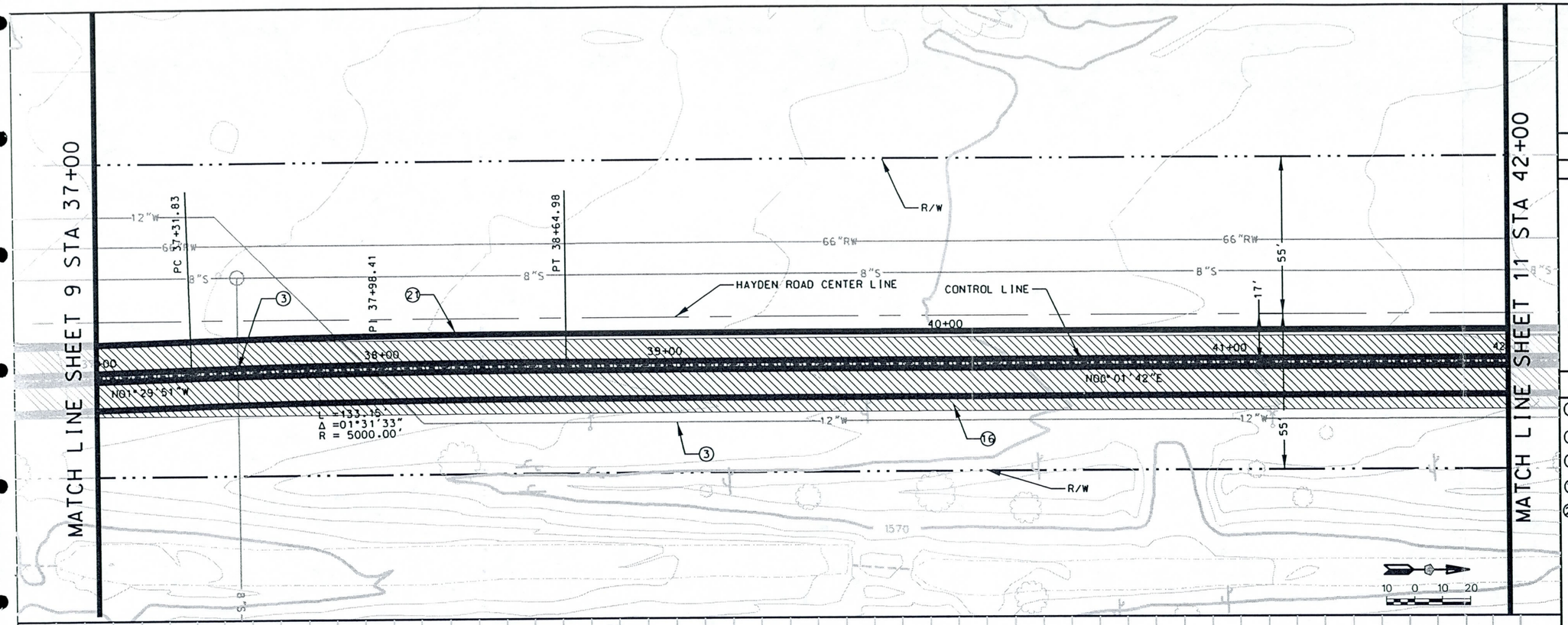
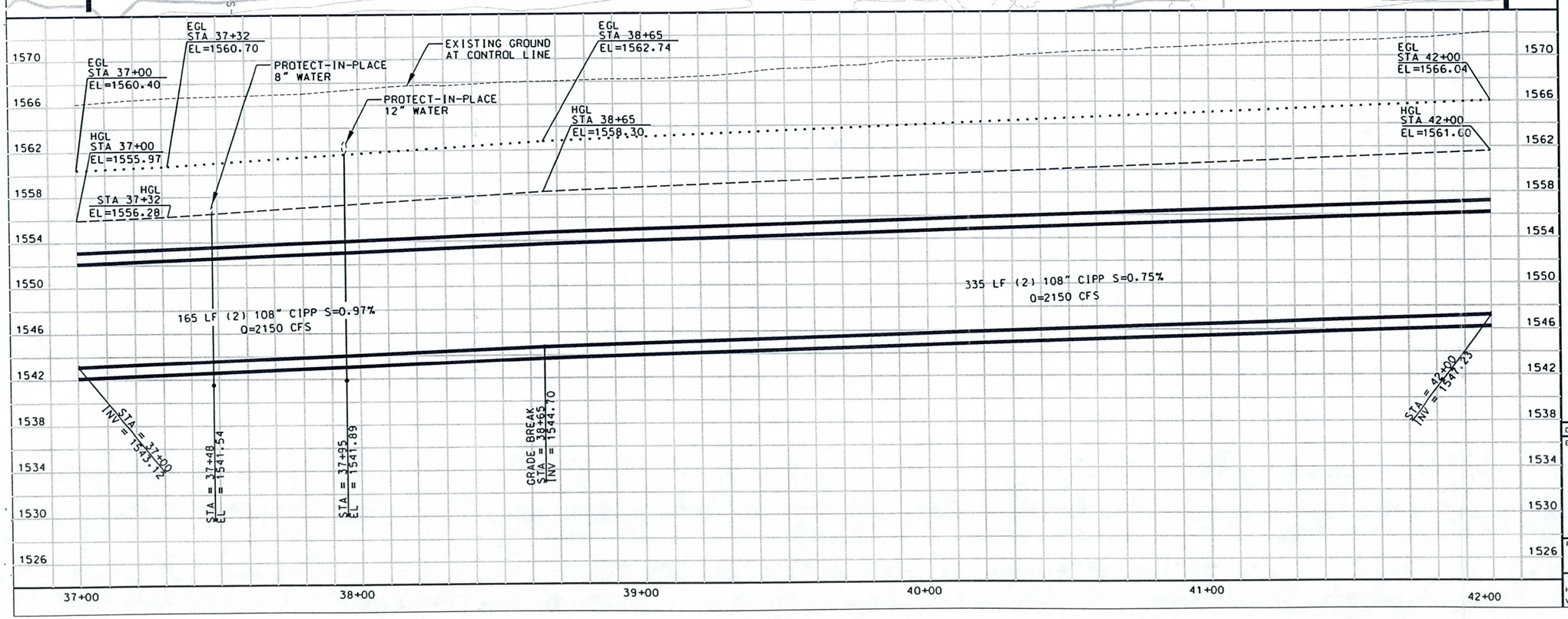
PROJECT TITLE: SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ. 1"=20'	TJC	9/18/98		8
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	8 OF 15





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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

1. INSTALL (2) 120" CIPP (SEE DETAIL A - SHEET 15)
2. INSTALL MANHOLES (2) PER MAG STD DTL 521
3. PROTECT IN PLACE ALL EXISTING UTILITIES EXECPT AS OTHERWISE NOTED
16. REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING
21. INSTALL (2) 108" CIPP (SEE DETAIL A - SHEET 15)

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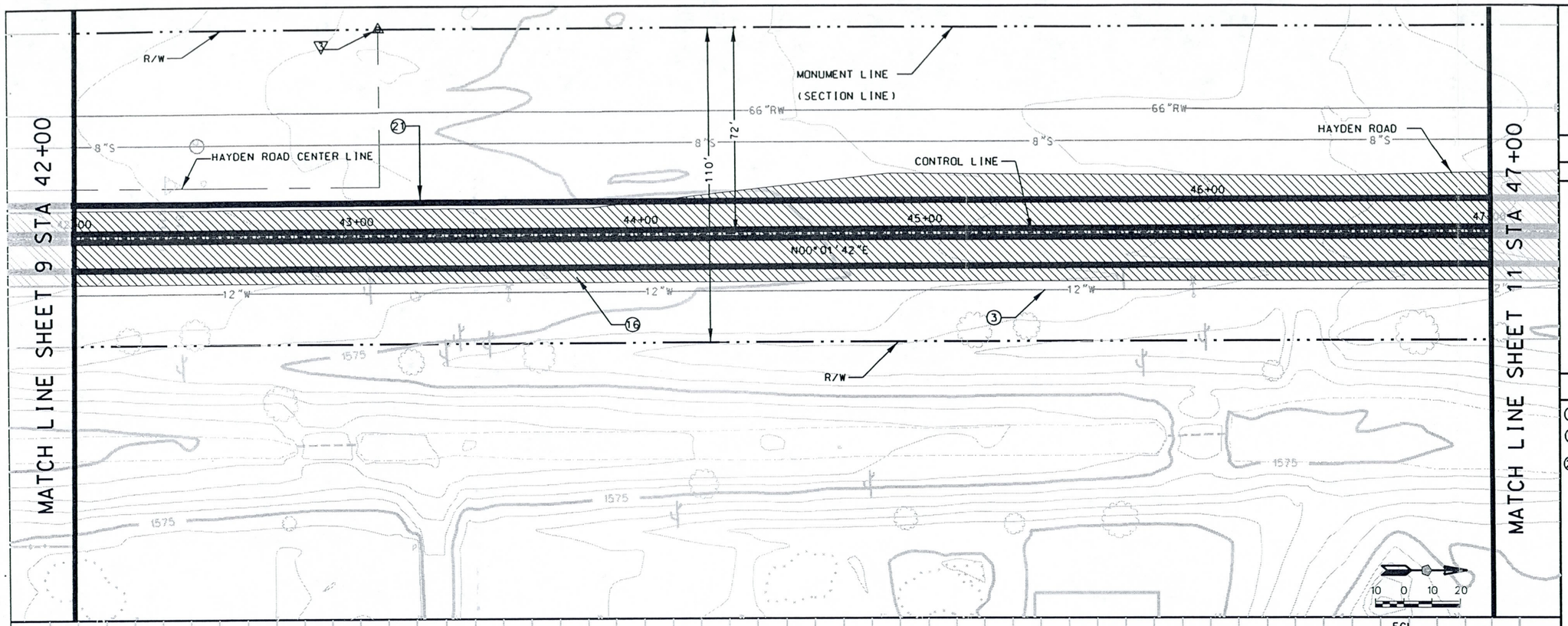
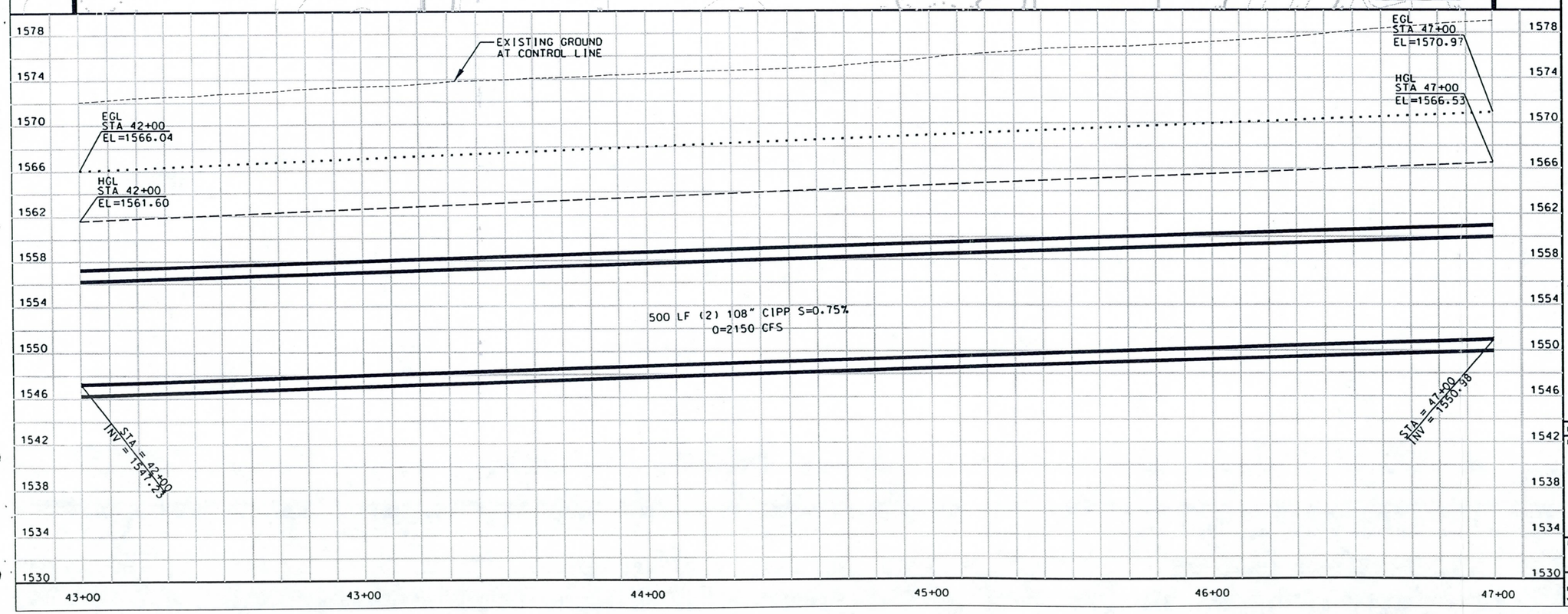
PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ. 1"=20'	TJC	9/18/98		9
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	9 OF 15





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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

③ PROTECT IN PLACE ALL EXISTING UTILITIES EXCEPT AS OTHERWISE NOTED

⑯ REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING

㉑ INSTALL (2) 108" CIPP (SEE DETAIL - A SHEET 15)

TEMPORARY BENCH MARK
SEE SHEET 2

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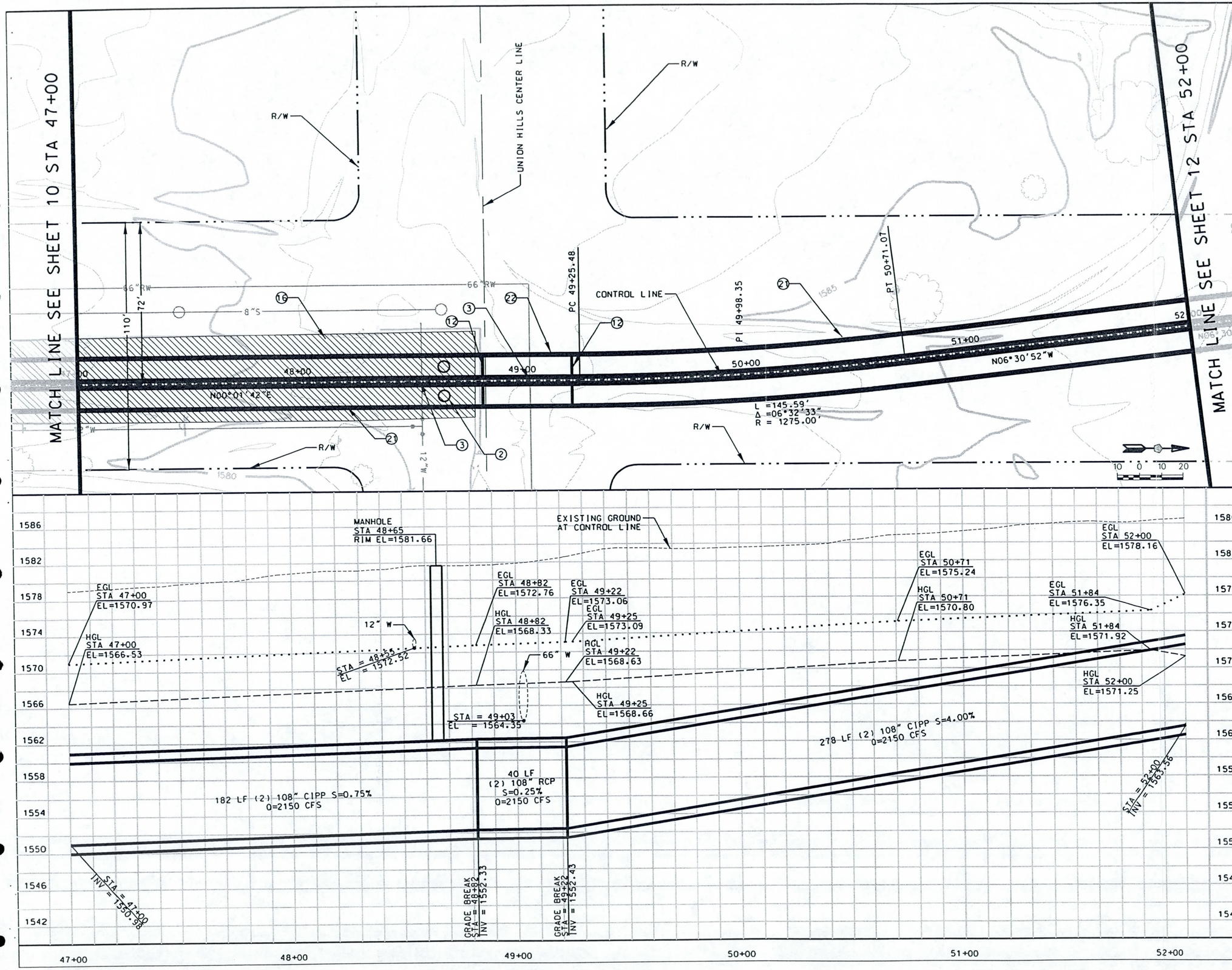
SCOTTSDALE, ARIZONA 85251

PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ. 1"=20'	TJC	9/18/98		10
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	10 OF 15



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

- ② INSTALL (2) MANHOLES PER MAG STD DTL 521
- ③ PROTECT IN PLACE ALL EXISTING UTILITIES
- ⑫ CONSTRUCT CONCRETE PIPE COLLAR (PER MAG STD DTL 505
- ⑯ REMOVE AND REPLACE EXISTING PAVEMENT. MATCH EXISTING
- ㉑ INSTALL (2) 108" CIPP (SEE DETAIL - A SHEET 15)
- ㉒ INSTALL (2) 108" RCP (SEE DETAIL - B SHEET 15)

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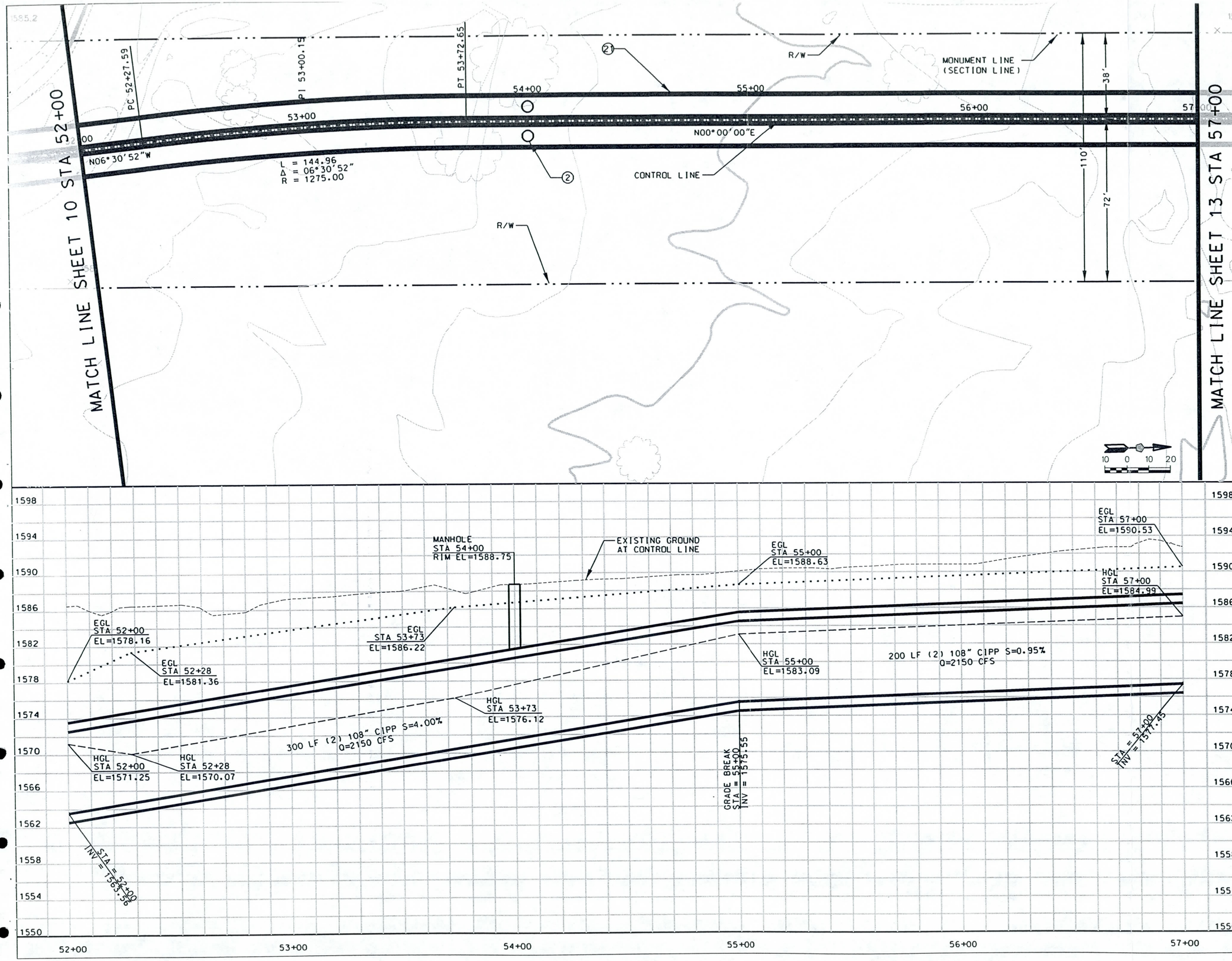
PROJECT TITLE: SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 11
HORIZ. 1"=20'	TJC	9/18/98		
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	11 OF 15



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

㉑ INSTALL (2) 108" CIPP
(SEE DETAIL - A SHEET 15)

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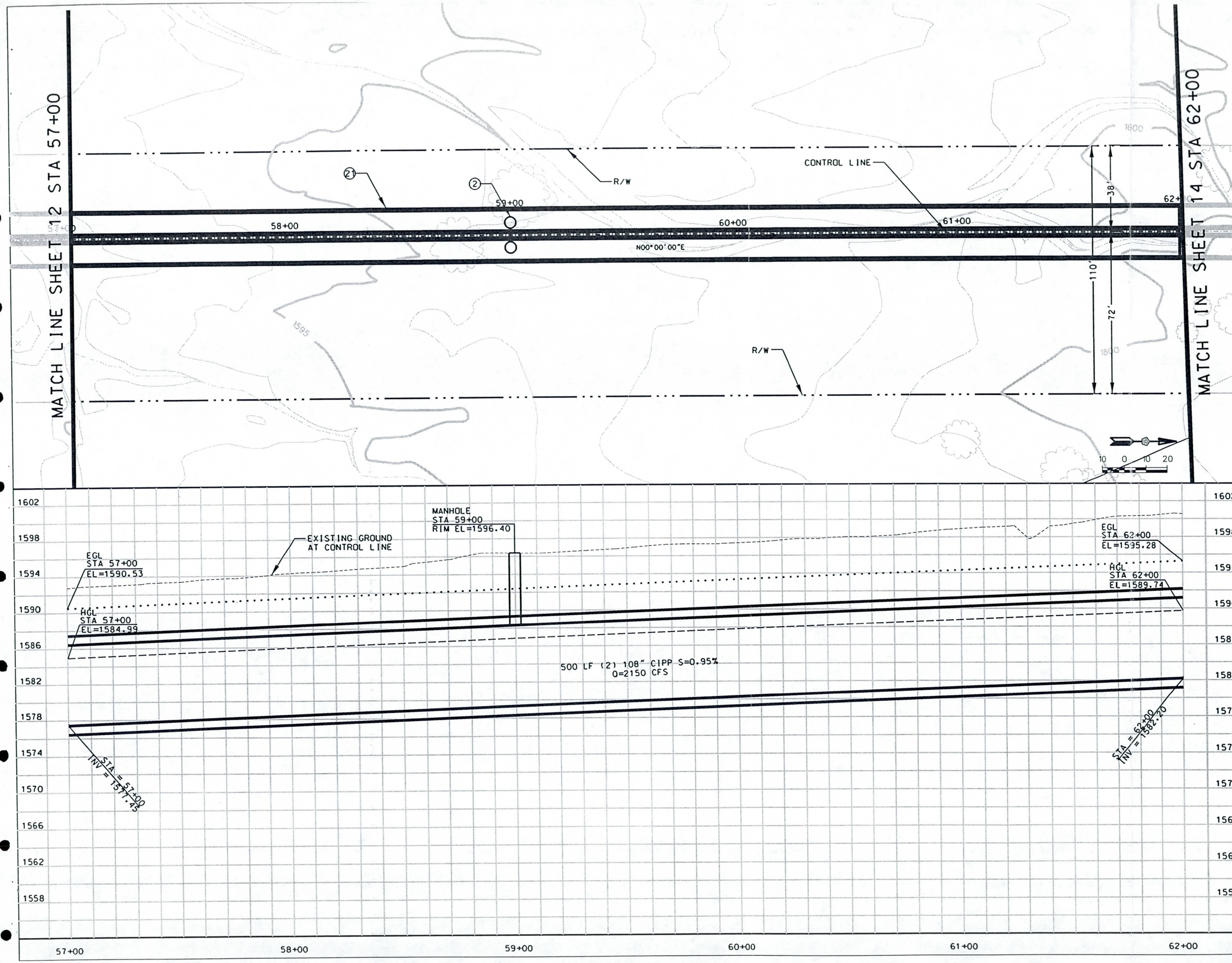
PROJECT TITLE
SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 12
HORIZ 1"=20'	TJC	9/18/98		
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	12 OF 15



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

(2) INSTALL MANHOLES (2) PER MAG STD DTL 521

(21) INSTALL (2) 108" CIPP (SEE DETAIL A - SHEET 15)

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PROJECT TITLE
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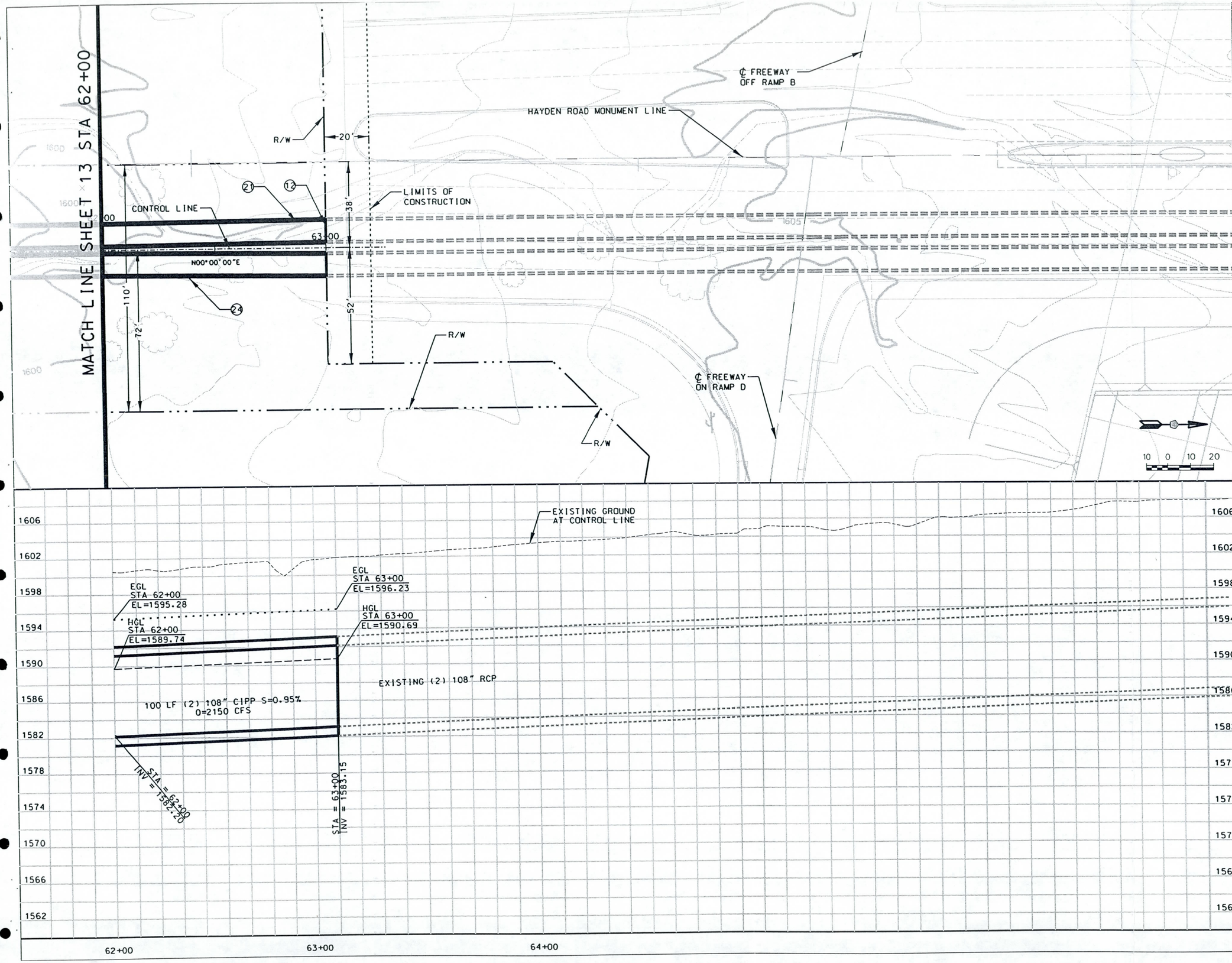
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ. 1"=20'	TJC	9/18/98		13
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	13 OF 15



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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

(12) CONSTRUCT CONCRETE PIPE COLLAR PER MAG STD DTL 505

(21) INSTALL (2) 108" CIPP (SEE DETAIL - A SHEET 15)

(24) TRANSITION PIPE SEPERATION FROM STA 62+00 TO STA 63+00

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PROJECT TITLE: SCOTTSDALE DESERT GREENBELT
HAYDEN ROAD STORM DRAIN

SCALE	DESIGNED BY	DATE	BID NO.	SHT. 14
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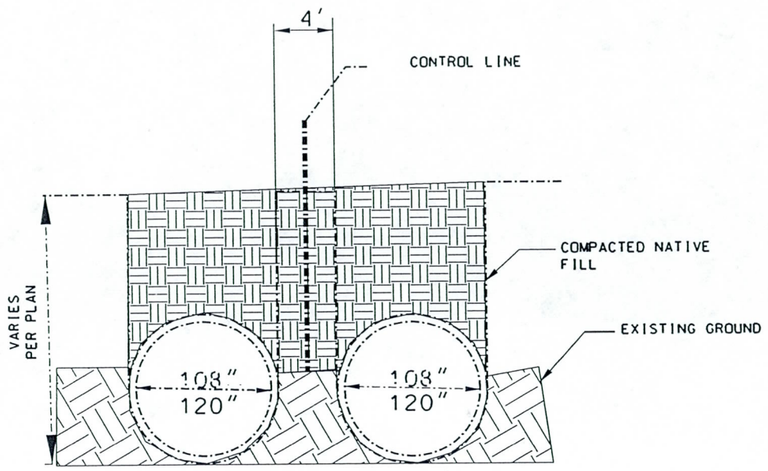
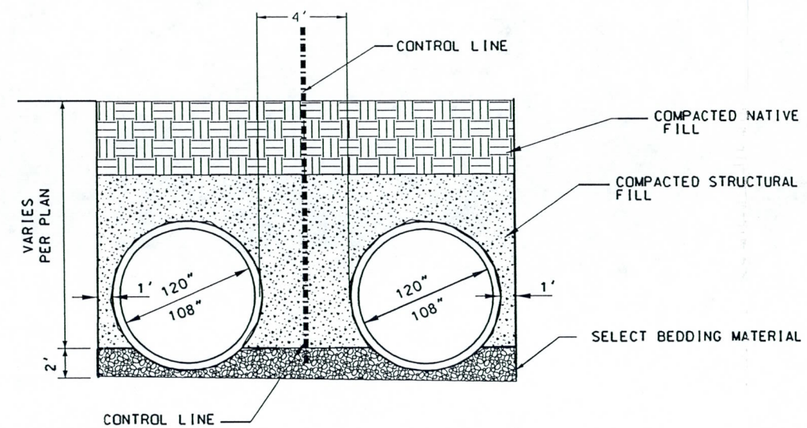
VERT. 1"=5'	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	14 OF 15



CAST-IN-PLACE PIPE (CIPP)

DETAIL "A"



REINFORCED CONCRETE PIPE (RCP)

DETAIL "B"

ENERGY DISSIPATOR

NOT SHOWN

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REMOVAL NOTES:

☐ Description	Unit	Quan.

○ CONSTRUCTION NOTES:

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SCALE	DESIGNED BY	DATE	BID NO.	SHT.
HORIZ. NTS	TJC	9/18/98		15
VERT.	DRAWN BY JEB	AS-BUILT	PROJECT NO. 5001.0007	15 OF 15

Appendix B

Hydraulic Calculations
&
References

Scottsdale Desert Greenbelt
Hayden Road Stormdrain
Analysis Summary

Station	Static Head (ft)			Hydraulic Grade Elevation			Energy Grade Elevation		
	StormCAD	Hand with impound	Hand * w/o impound	StormCAD	Hand with impound	Hand * w/o impound	StormCAD	Hand with impound	Hand * w/o impound
11+45	10.00	10.00	7.88	1,531.0	1,531.0	1,528.9	1,533.9	1,533.9	1,533.0
12+65	10.38	11.66	11.03	1,531.7	1,533.0	1,532.3	1,534.6	1,535.9	1,535.2
13+85	11.48	13.32	12.69	1,533.1	1,534.9	1,534.3	1,536.0	1,537.8	1,537.2
15+45	12.71	13.60	12.97	1,534.7	1,535.6	1,535.0	1,537.6	1,538.5	1,537.9
19+22	11.57	12.92	12.30	1,536.8	1,538.2	1,537.6	1,539.7	1,541.1	1,540.5
20+13	11.53	12.65	12.02	1,537.6	1,538.7	1,538.1	1,540.5	1,541.6	1,541.0
22+82	10.74	12.33	11.70	1,539.1	1,540.7	1,540.0	1,542.0	1,543.6	1,543.0
22+82		10.52	9.89		1,539.9	1,539.2		1,544.3	1,543.7
25+12	12.89	10.53	9.90	1,544.5	1,542.1	1,541.5	1,548.9	1,546.6	1,545.9
26+70	12.92	11.27	10.64	1,546.1	1,544.4	1,543.8	1,550.5	1,548.8	1,548.2
26+82	13.28	11.27	10.64	1,546.5	1,544.5	1,543.9	1,551.0	1,548.9	1,548.3
30+87	13.34	12.04	11.41	1,550.5	1,549.2	1,548.6	1,555.0	1,553.6	1,553.0
34+32	13.74	12.09	11.46	1,554.3	1,552.6	1,552.0	1,558.7	1,557.0	1,556.4
35+65	13.77	12.83	12.20	1,555.6	1,554.6	1,554.0	1,560.0	1,559.1	1,558.4
37+32	14.15	12.85	12.22	1,557.6	1,556.3	1,555.7	1,562.0	1,560.7	1,560.1
38+65	14.17	13.58	12.95	1,558.9	1,558.3	1,557.7	1,563.3	1,562.7	1,562.1
48+82	16.95	16.00	15.37	1,569.3	1,568.3	1,567.7	1,573.7	1,572.8	1,572.1
49+22	17.25	16.19	15.57	1,569.7	1,568.6	1,568.0	1,574.1	1,573.1	1,572.4
49+25	17.14	16.09	15.46	1,569.7	1,568.7	1,568.0	1,574.2	1,573.1	1,572.5
50+71	12.76	12.41	11.78	1,571.2	1,570.8	1,570.2	1,575.6	1,575.2	1,574.6
52+28	7.93**	5.40	5.40	1,572.6	1,570.1	1,570.1	1,577.7	1,581.4	1,581.4
53+73	7.93**	5.66	5.66	1,578.4	1,576.1	1,576.1	1,583.5	1,586.2	1,586.2
55+00	7.93**	7.54	7.54	1,583.5	1,583.1	1,583.1	1,588.6	1,588.6	1,588.6
63+00	7.93**	7.54	7.54	1,591.1	1,590.7	1,590.7	1,596.2	1,596.2	1,596.2

* Critical pipe flow depth used at station 11+45
** Critical Depth assumed by StormCAD

Scottsdale Desert Greenbelt
Hayden Road Stormdrain
StormCAD Output

Station	Pipe Diameter (in)	Invert (Elev)	Static Head (ft)	HGL (Elev)	EGL (Elev)	Energy Slope (ft/ft)	Length (ft)	Average Velocity (fps)	Flow (cfs)
63+00	108	1,583.15	7.93	1,591.08	1,596.18	0.0095	800	18.1	2,150
55+00	108	1,575.55	7.93	1,583.48	1,588.58	0.0396	127	17.8	2,150
53+73	108	1,570.46	7.93	1,578.39	1,583.49	0.0399	145	18.1	2,150
52+28	108	1,564.67	7.93	1,572.60	1,577.70	0.0112	157	17.5	2,150
50+71	108	1,558.39	12.76	1,571.15	1,575.59	0.0099	146	16.9	2,150
49+25	108	1,552.57	17.14	1,569.71	1,574.15	0.0099	3	16.9	2,150
49+22	108	1,552.43	17.25	1,569.68	1,574.12	0.0099	40	16.9	2,150
48+82	108	1,552.33	16.95	1,569.28	1,573.72	0.0099	1,017	16.9	2,150
38+65	108	1,544.72	14.17	1,558.89	1,563.33	0.0099	133	16.9	2,150
37+32	108	1,543.43	14.15	1,557.58	1,562.02	0.0099	167	16.9	2,150
35+65	108	1,541.81	13.77	1,555.58	1,560.01	0.0099	133	16.9	2,150
34+32	108	1,540.52	13.74	1,554.26	1,558.70	0.0099	345	16.9	2,150
30+87	108	1,537.17	13.34	1,550.51	1,554.95	0.0099	405	16.9	2,150
26+82	108	1,533.24	13.28	1,546.52	1,550.95	0.0099	12	16.9	2,150
26+70	108	1,533.13	12.92	1,546.05	1,550.49	0.0099	158	16.9	2,150
25+12	108	1,531.60	12.89	1,544.49	1,548.93	0.0099	230	16.9	2,150
22+82	108	1,528.34	10.74	1,539.08	1,541.99	0.0056	269	13.7	2,150
20+13	120	1,526.04	11.53	1,537.57	1,540.48	0.0056	91	13.7	2,150
19+22	120	1,525.26	11.57	1,536.83	1,539.74	0.0056	377	13.7	2,150
15+45	120	1,522.00	12.71	1,534.71	1,537.62	0.0056	160	13.7	2,150
13+85	120	1,521.60	11.48	1,533.08	1,535.99	0.0056	120	13.7	2,150
12+65	120	1,521.30	10.38	1,531.68	1,534.59	0.0056	120	13.7	2,150
11+45	120	1,521.00	10.00	1,531.00	1,533.91	0.0018	0	13.7	2,150

Scottsdale Desert Greenbelt
Hayden Road Stormdrain
Hand Calculations - with downstream impoundment

Subcritical Flow - Station begin downstream

Culvert Description	Station	Invert Elev	K_{cut}	K_{bend}	K_{minor}	Flowrate (cfs)	Pipe Diameter (in)	Manning's n	Static Head (ft)	HGL Elevation	Σ Minor Loss K	θ (rad)	Flow Area (sf)	Flow Wetted Perimeter (ft)	Hydraulic radius (ft)	Velocity (fps)	Velocity Head (ft)	Pipe Length (ft)	Pipe Slope (ft/ft)	Average Velocity (fps)	Friction Slope S_f (ft/ft)	Friction Loss H_f (ft)	Minor Loss H_m (ft)	Energy Grade Elevation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	16.0	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Outlet	11+45	1521.00	0.00	0.00	0.00				10.00	1531.00	0.00	3.14	78.54	31.42	2.50	13.7	2.91							1533.91
Pipe						1075	120	0.013										120	0.0025	13.69	0.01028	1.23		
Upstream Junction	12+65	1521.30	0.00	0.25	0.00				11.66	1532.96	0.25	3.14	78.54	31.42	2.50	13.7	2.91						0.73	1535.87
Pipe						1075	120	0.013										120	0.0025	13.69	0.01028	1.23		
Upstream Junction	13+85	1521.60	0.00	0.25	0.00				13.32	1534.92	0.25	3.14	78.54	31.42	2.50	13.7	2.91						0.73	1537.83
Pipe						1075	120	0.013										160	0.0025	13.69	0.00422	0.68		
Upstream Junction	15+45	1522.00	0.00	0.00	0.00				13.60	1535.60	0.00	3.14	78.54	31.42	2.50	13.7	2.91						0.00	1538.51
Pipe						1075	120	0.015										377	0.0086	13.69	0.00624	2.35		
Upstream Junction	19+22	1525.26	0.00	0.08	0.00				12.92	1538.18	0.08	3.14	78.54	31.42	2.50	13.7	2.91						0.23	1541.09
Pipe						1075	120	0.015										90	0.0087	13.69	0.00562	0.51		
Upstream Junction	20+13	1526.04	0.00	0.00	0.00				12.65	1538.69	0.00	3.14	78.54	31.42	2.50	13.7	2.91						0.00	1541.60
Pipe						1075	120	0.015										269	0.0085	13.69	0.00648	1.75		
Upstream Junction	22+82	1528.34	0.00	0.08	0.00				12.33	1540.67	0.08	3.14	78.54	31.42	2.50	13.7	2.91						0.23	1543.58
Pipe						1075	108	0.015										0	100.0000	15.29	0.00562	0.00		
Upstream Junction	22+82	1529.34	0.00	0.00	0.16				10.52	1539.86	0.16	3.14	63.62	28.27	2.25	16.9	4.43						0.71	1544.29
Pipe						1075	108	0.015										230	0.0098	16.90	0.00986	2.27		
Upstream Junction	25+12	1531.60	0.00	0.00	0.00				10.53	1542.12	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1546.56
Pipe						1075	108	0.015										158	0.0097	16.90	0.01210	1.92		
Upstream Junction	26+70	1533.13	0.00	0.08	0.00				11.27	1544.40	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1548.83
Pipe						1075	108	0.015										11	0.0097	16.90	0.00986	0.11		
Upstream Junction	26+82	1533.24	0.00	0.00	0.00				11.27	1544.51	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1548.94
Pipe						1075	108	0.015										405	0.0097	16.90	0.01074	4.35		
Upstream Junction	30+87	1537.17	0.00	0.08	0.00				12.04	1549.21	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1553.65
Pipe						1075	108	0.015										344	0.0097	16.90	0.00986	3.40		
Upstream Junction	34+32	1540.52	0.00	0.00	0.00				12.09	1552.61	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1557.04
Pipe						1075	108	0.015										133	0.0097	16.90	0.01252	1.67		
Upstream Junction	35+65	1541.81	0.00	0.08	0.00				12.83	1554.64	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1559.07
Pipe						1075	108	0.015										167	0.0097	16.90	0.00986	1.64		
Upstream Junction	37+32	1543.43	0.00	0.00	0.00				12.85	1556.28	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1560.71
Pipe						1075	108	0.015										133	0.0097	16.90	0.01252	1.67		
Upstream Junction	38+65	1544.72	0.00	0.08	0.00				13.58	1558.30	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1562.74

Scottsdale Desert Greenbelt
Hayden Road Stormdrain
Hand Calculations - with downstream impoundment

Subcritical Flow - Station begin downstream

Culvert Description	Station	Invert Elev	K_{ent}	K_{bend}	K_{minor}	Flowrate (cfs)	Pipe Diameter (in)	Manning's n	Static Head (ft)	HGL Elevation	Σ Minor Loss K	θ (rad)	Flow Area (sf)	Flow Wetted Perimeter (ft)	Hydraulic radius (ft)	Velocity (fps)	Velocity Head (ft)	Pipe Length (ft)	Pipe Slope (ft/ft)	Average Velocity (fps)	Friction Slope S_f (ft/ft)	Friction Loss H_f (ft)	Minor Loss H_m (ft)	Energy Grade Elevation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	16.0	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Upstream Junction	38+65	1544.72	0.00	0.08	0.00				13.58	1558.30	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1562.74
Pipe						1075	108	0.015										1017	0.0075	16.90	0.00986	10.03		
Upstream Junction	48+82	1552.33	0.00	0.00	0.00				16.00	1568.33	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1572.76
Pipe						1075	108	0.013										40	0.0025	16.90	0.00741	0.30		
Upstream Junction	49+22	1552.43	0.00	0.00	0.00				16.19	1568.63	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1573.06
Pipe						1075	108	0.015										3	0.0400	16.90	0.00986	0.03		
Upstream Junction	49+25	1552.57	0.00	0.00	0.00				16.09	1568.66	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1573.09
Pipe						1075	108	0.015										146	0.0400	16.90	0.01230	1.79		
Upstream Junction	50+71	1558.39	0.00	0.08	0.00				12.41	1570.80	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1575.24
Pipe						1075	108	0.015										113	0.0400	16.90	0.00986	1.12		
Upstream Junction	51+84	1562.92	0.00	0.00	0.00				9.00	1571.92	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1576.35
Pipe						1075	108	0.015										44	0.0400	21.93	0.00986	0.43		
Upstream Junction	52+28	1564.67	0.00	0.00	0.00				5.40	1570.07	0.00	1.77	39.88	15.96	2.50	27.0	11.28						0.00	1581.36
Pipe						1075	108	0.015										145	0.0400	26.23	0.02804	4.06		
Upstream Junction	53+73	1570.46	0.00	0.08	0.00				5.66	1576.12	0.08	1.83	42.15	16.49	2.56	25.5	10.10						0.81	1586.22
Pipe						1075	108	0.015										127	0.0400	22.20	0.01894	2.41		
Upstream Junction	55+00	1575.55	0.00	0.00	0.00				7.54	1583.09	0.00	2.31	56.91	20.81	2.73	18.9	5.54						0.00	1588.63
Pipe						1075	108	0.015										800	0.0095	18.89	0.00950	7.60		
Upstream Junction	63+00	1583.15	0.00	0.00	0.00				7.54	1590.69	0.00	2.31	56.91	20.81	2.73	18.9	5.54						0.00	1596.23

Scottsdale Desert Greenbelt
Hayden Road Stormdrain
Hand Calculations - without downstream impoundment

Subcritical Flow - Station begin downstream

Culvert Description	Station	Invert Elev	K_{ent}	K_{bend}	K_{minor}	Flowrate (cfs)	Pipe Diameter (in)	Manning's n	Static Head (ft)	HGL Elevation	Σ Minor Loss K	θ (rad)	Flow Area (sf)	Flow Wetted Perimeter (ft)	Hydraulic radius (ft)	Velocity (fps)	Velocity Head (ft)	Pipe Length (ft)	Pipe Slope (ft/ft)	Average Velocity (fps)	Friction Slope S_f (ft/ft)	Friction Loss H_f (ft)	Minor Loss H_m (ft)	Energy Grade Elevation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	16.0	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Outlet	11+45	1521.00	0.00	0.00	0.00				7.88	1528.88	0.00	2.19	66.43	21.86	3.04	16.2	4.07							1532.95
Pipe						1075	120	0.013										120	0.0025	14.94	0.01302	1.56		
Upstream Junction	12+65	1521.30	0.00	0.25	0.00				11.03	1532.33	0.25	3.14	78.54	31.42	2.50	13.7	2.91						0.73	1535.24
Pipe						1075	120	0.013										120	0.0025	13.69	0.01028	1.23		
Upstream Junction	13+85	1521.60	0.00	0.25	0.00				12.69	1534.29	0.25	3.14	78.54	31.42	2.50	13.7	2.91						0.73	1537.20
Pipe						1075	120	0.013										160	0.0025	13.69	0.00422	0.68		
Upstream Junction	15+45	1522.00	0.00	0.00	0.00				12.97	1534.97	0.00	3.14	78.54	31.42	2.50	13.7	2.91						0.00	1537.88
Pipe						1075	120	0.015										377	0.0086	13.69	0.00624	2.35		
Upstream Junction	19+22	1525.26	0.00	0.08	0.00				12.30	1537.56	0.08	3.14	78.54	31.42	2.50	13.7	2.91						0.23	1540.46
Pipe						1075	120	0.015										90	0.0087	13.69	0.00562	0.51		
Upstream Junction	20+13	1526.04	0.00	0.00	0.00				12.02	1538.06	0.00	3.14	78.54	31.42	2.50	13.7	2.91						0.00	1540.97
Pipe						1075	120	0.015										269	0.0085	13.69	0.00648	1.75		
Upstream Junction	22+82	1528.34	0.00	0.08	0.00				11.70	1540.04	0.08	3.14	78.54	31.42	2.50	13.7	2.91						0.23	1542.95
Pipe						1075	108	0.015										0	100.0000	15.29	0.00562	0.00		
Upstream Junction	22+82	1529.34	0.00	0.00	0.16				9.89	1539.23	0.16	3.14	63.62	28.27	2.25	16.9	4.43						0.71	1543.66
Pipe						1075	108	0.015										230	0.0098	16.90	0.00986	2.27		
Upstream Junction	25+12	1531.60	0.00	0.00	0.00				9.90	1541.49	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1545.93
Pipe						1075	108	0.015										158	0.0097	16.90	0.01210	1.92		
Upstream Junction	26+70	1533.13	0.00	0.08	0.00				10.64	1543.77	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1548.20
Pipe						1075	108	0.015										11	0.0097	16.90	0.00986	0.11		
Upstream Junction	26+82	1533.24	0.00	0.00	0.00				10.64	1543.88	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1548.31
Pipe						1075	108	0.015										405	0.0097	16.90	0.01074	4.35		
Upstream Junction	30+87	1537.17	0.00	0.08	0.00				11.41	1548.58	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1553.02
Pipe						1075	108	0.015										344	0.0097	16.90	0.00986	3.40		
Upstream Junction	34+32	1540.52	0.00	0.00	0.00				11.46	1551.98	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1556.41
Pipe						1075	108	0.015										133	0.0097	16.90	0.01252	1.67		
Upstream Junction	35+65	1541.81	0.00	0.08	0.00				12.20	1554.01	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1558.44
Pipe						1075	108	0.015										167	0.0097	16.90	0.00986	1.64		
Upstream Junction	37+32	1543.43	0.00	0.00	0.00				12.22	1555.65	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1560.08
Pipe						1075	108	0.015										133	0.0097	16.90	0.01252	1.67		
Upstream Junction	38+65	1544.72	0.00	0.08	0.00				12.95	1557.67	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1562.11

Scottsdale Desert Greenbelt
Hayden Road Stormdrain
Hand Calculations - without downstream impoundment

Subcritical Flow - Station begin downstream

Culvert Description	Station	Invert Elev	K_{ent}	K_{bend}	K_{minor}	Flowrate (cfs)	Pipe Diameter (in)	Manning's n	Static Head (ft)	HGL Elevation	Σ Minor Loss K	θ (rad)	Flow Area (sf)	Flow Wetted Perimeter (ft)	Hydraulic radius (ft)	Velocity (fps)	Velocity Head (ft)	Pipe Length (ft)	Pipe Slope (ft/ft)	Average Velocity (fps)	Friction Slope S_f (ft/ft)	Friction Loss H_f (ft)	Minor Loss H_m (ft)	Energy Grade Elevation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	16.0	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Upstream Junction	38+65	1544.72	0.00	0.08	0.00				12.95	1557.67	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1562.11
Pipe						1075	108	0.015										1017	0.0075	16.90	0.00986	10.03		
Upstream Junction	48+82	1552.33	0.00	0.00	0.00				15.37	1567.70	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1572.13
Pipe						1075	108	0.013										40	0.0025	16.90	0.00741	0.30		
Upstream Junction	49+22	1552.43	0.00	0.00	0.00				15.57	1568.00	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1572.43
Pipe						1075	108	0.015										3	0.0400	16.90	0.00986	0.03		
Upstream Junction	49+25	1552.57	0.00	0.00	0.00				15.46	1568.03	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1572.46
Pipe						1075	108	0.015										146	0.0400	16.90	0.01230	1.79		
Upstream Junction	50+71	1558.39	0.00	0.08	0.00				11.78	1570.18	0.08	3.14	63.62	28.27	2.25	16.9	4.43						0.35	1574.61
Pipe						1075	108	0.015										92	0.0400	16.90	0.00986	0.91		
Upstream Junction	51+64	1562.09	0.00	0.00	0.00				9.00	1571.09	0.00	3.14	63.62	28.27	2.25	16.9	4.43						0.00	1575.52
Pipe						1075	108	0.015										65	0.0400	21.93	0.00986	0.64		
Upstream Junction	52+28	1564.67	0.00	0.00	0.00				5.40	1570.07	0.00	1.77	39.88	15.96	2.50	27.0	11.28						0.00	1581.36
Pipe						1075	108	0.015										145	0.0400	26.23	0.02804	4.06		
Upstream Junction	53+73	1570.46	0.00	0.08	0.00				5.66	1576.12	0.08	1.83	42.15	16.49	2.56	25.5	10.10						0.81	1586.22
Pipe						1075	108	0.015										127	0.0400	22.20	0.01894	2.41		
Upstream Junction	55+00	1575.55	0.00	0.00	0.00				7.54	1583.09	0.00	2.31	56.91	20.81	2.73	18.9	5.54						0.00	1588.63
Pipe						1075	108	0.015										800	0.0095	18.89	0.00950	7.60		
Upstream Junction	63+00	1583.15	0.00	0.00	0.00				7.54	1590.69	0.00	2.31	56.91	20.81	2.73	18.9	5.54						0.00	1596.23

* from reference #1

these losses, the culvert should be curved or have bends not exceeding 15-degrees at intervals of not less than 50 feet (15m). (30) Under these conditions, bend losses can normally be ignored.

If headwater and flow considerations are critical, accurate hydraulic analysis of bend losses may be required. Bend losses are a function of the velocity head in the culvert barrel. To calculate bend losses, use the following equation.

$$H_b = K_b \left(\frac{V^2}{2g} \right) \qquad (21)$$

H_b is added to the other outlet losses in equation (1). Bend loss coefficients (K_b) are found in various references. (24, 31, 32) Reference (32) suggests the coefficients in Table 6 for bend losses in conduits flowing full.

The broken back culvert shown in Figure VI-3 has four possible control sections: the inlet, the outlet, and the two bends.

The upstream bend may act as a control section, with the flow passing through critical depth just upstream of the bend. In this case, the upstream section of the culvert operates in outlet control and the downstream section operates in inlet control. Outlet control calculation procedures can be applied to the upstream barrel, assuming critical depth at the bend, to obtain a headwater elevation. This elevation is then compared with the inlet and outlet control headwater elevations for the overall culvert. These headwaters are determined using the design procedures of Chapter III. The controlling flow condition produces the highest headwater elevation. Control at the lower bend is very unlikely and that possible control section can be ignored except for the bend losses in outlet control. Broken-back culverts can also be analyzed in detail using standard backwater and drawdown calculation methods. (31)

4. Junctions. Flow from two or more separate culverts or storm sewers may be combined at a junction into a single culvert barrel. For example, a tributary and a main stream intersecting at a roadway crossing can be accommodated by a culvert junction. (figure VI-5) A drainage pipe collecting runoff from the overlying roadway surface and discharging into a culvert barrel is an example of a storm sewer/culvert junction.

Loss of head may be important in the hydraulic design of a culvert containing a junction. Attention should be given to streamlining the junction to minimize turbulence and head loss. Also, timing of peak flows from the two branches should

Table 6 Loss coefficients for bends.

Radius of Bend	Angle of Bend, degrees		
Equivalent Diameter	90°	45°	22.5°
1	0.50	0.37	0.25
2	.30	.22	.15
4	.25	.19	.12
6	.15	.11	.08
8	.15	.11	.08

* from reference #1

TABLE 12 - ENTRANCE LOSS COEFFICIENTS

Outlet Control, Full or Partly Full Entrance head loss

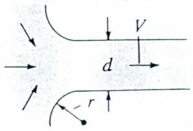
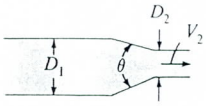
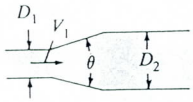
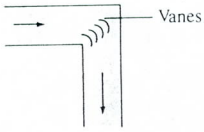
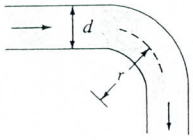
$$H_e = k_e \left(\frac{V^2}{2g} \right)$$

Type of Structure and Design of Entrance	Coefficient k_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side-or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side-or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side-or slope-tapered inlet	0.2

*Note: "End Section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be

from reference #6

TABLE 10.2 LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

Description	Sketch	Additional Data	K		Source
Pipe entrance		r/d	K_e		(2)
		0.0	0.50		
		0.1	0.12		
$h_L = K_e V^2/2g$		>0.2	0.03		
Contraction		D_2/D_1	K_C $\theta = 60°$	K_C $\theta = 180°$	(2)
		0.0	0.08	0.50	
		0.20	0.08	0.49	
		0.40	0.07	0.42	
		0.60	0.06	0.32	
		0.80	0.05	0.18	
$h_L = K_C V_2^2/2g$		0.90	0.04	0.10	
Expansion		D_1/D_2	K_E $\theta = 10°$	K_E $\theta = 180°$	(2)
		0.0		1.00	
		0.20	0.13	0.92	
		0.40	0.11	0.72	
		0.60	0.06	0.42	
$h_L = K_E V_1^2/2g$		0.80	0.03	0.16	
90° miter bend		Without vanes	$K_b = 1.1$		(36)
		With vanes	$K_b = 0.2$		(36)
90° smooth bend		r/d			(5) and (19)
		1	$K_b = 0.35$		
		2	0.19		
		4	0.16		
		6	0.21		
		8	0.28		
		10	0.32		
Threaded pipe fittings	Globe valve—wide open	$K_v = 10.0$			(36)
	Angle valve—wide open	$K_v = 5.0$			
	Gate valve—wide open	$K_v = 0.2$			
	Gate valve—half open	$K_v = 5.6$			
	Return bend	$K_b = 2.2$			
	Tee				
	straight-through flow	$K_t = 0.4$			
	side-outlet flow	$K_t = 1.8$			
	90° elbow	$K_b = 0.9$			
	45° elbow	$K_b = 0.4$			