CITY OF DAVIS
CORROSION STUDY
CIP No. 8141
FINAL REPORT
MAY 2006

Prepared for:
City of Davis, California

Prepared by:
RBF Consulting
40810 County Center Drive, Suite 100
Temecula, California 92591
May 20, 2006

Mr. Terry Jue, PE
Associate Civil Engineer
Public Works Department
City of Davis
1717 Fifth Street
Davis, California 95616

Subject: Evaluation of Corrosion and Corrosion Failures In The City of Davis Water Distribution System

Dear Mr. Jue:

During March we conducted a field investigation within various areas of the City in order to try and determine a cause for the corrosion failure of the City’s ductile iron pipe and copper services of the water distribution system.

The investigation included inspections of failed piping components stored in the PW maintenance yard as well as actual failure sites located within the system. Also the inspection included collecting soils samples for laboratory testing and the recording of pipe-to-soil potential measurements from various service locations.

In addition to the potential measurements, we investigated the potential for stray AC current interference from gas company pipelines within the City’s service area. This inspection included reading several test stations on gas pipelines in order to identify the output “signature” of impressed current rectifiers operated by the gas company. We then tested various locations in the City’s system to try and determine if the gas company rectifiers were inducing interfering currents on the water system piping and wells and thus promoting corrosion failures.

These tests were conducted using available copper service connections to the distribution system and well casings. Any electrical current spikes were read and recorded using a Fluke Model 97 portable oscilloscope. The readings were negligible and inconclusive thus proving that the gas company pipelines are well wrapped with a dielectric coating that prevents leakage of cathodic currents.

However, stray DC currents from household grounding systems were detected on copper services and these stray currents are known to not only affect the service but also metallic water mains when the service is directly tapped into the wall of the distribution pipe as is common with ductile iron pipe construction. The specific corrosion attack of the ductile iron from the direct connection of copper services is referred to as “galvanic”. The direct connection of the copper accelerates corrosion of the iron pipe that acts as the anode of a galvanic corrosion cell where as the copper acts as the cathode.
Additionally, underground electrical utility neutral cables also accelerate the ductile iron corrosion rate due to the fact that the neutral is interconnected with the water piping system in each residence.

Pipe failure due to stray current corrosion is more rapid than that from soil side corrosion due to the fact that metal loss is greater over a shorter period of time. This was evident of the specimens of failed pipe we inspected in the yard.

Soil samples collected from various locations, as illustrated in the appendix, were tested for pH, chlorides, sulfates, ammonia and resistivity. The results, which are included in the appendix, indicate that the area soils are corrosive to buried metallic structures including iron, steel and copper. The following is a summary of the laboratory soils testing.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Obtained From</th>
<th>Alkalinity* (mg/kg)</th>
<th>Sulfates* (% by wt.)</th>
<th>Chlorides* (mg/kg)</th>
<th>Ammonia* (mg/kg)</th>
<th>pH*</th>
<th>Resistivity* (ohm-m)</th>
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<tbody>
<tr>
<td>1</td>
<td>3334 Chesapeake</td>
<td>550</td>
<td>0.00056</td>
<td>ND</td>
<td>ND</td>
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<td>2</td>
<td>Pipe Backfill</td>
<td>250</td>
<td>0.00064</td>
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<td>ND</td>
<td>9.21</td>
<td>11,000</td>
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<td>3</td>
<td>2519 Rockwell</td>
<td>1500</td>
<td>0.0011</td>
<td>7.1</td>
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<td>6.84</td>
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<td>ND</td>
<td>9.07</td>
<td>12,000</td>
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<tr>
<td>5</td>
<td>315 Anza</td>
<td>1500</td>
<td>0.0212</td>
<td>6.3</td>
<td>ND</td>
<td>8.85</td>
<td>5,900</td>
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</tbody>
</table>

* Per attached results tested by Del Mar Analytical, Irvine per test method numbers EPA 300.0 for sulfates and chlorides, SW2320B-MOD for alkalinity, EPA 126.1-MOD for resistivity and EPA 9045C for pH.

Specimens of failed copper services and ductile iron pipe were also collected. The iron pipe exhibited "galvanization" and galvanic corrosion that result in the loss of iron from the carbon/iron matrix that makes up the pipe wall. Large penetrations in the ductile iron pipe indicate significant rapid metal loss. This also was noted and reported on in the report prepared by the Ductile Iron Pipe Research Association, dated November 18, 2002. The copper service pipe specimens were extensively pitted and penetrations were visible on the specimen seen in the attached photographs. Both of these pipe types exhibit corrosion resulting from corrosive soils and stray currents.

Factors promoting corrosion of copper and ductile iron in soil are 1) low resistivity (ability to conduct current); 2) Sulfate Reducing Bacteria (SRB); 3) differences in soil types and aeration; 4) ammonia (from fertilizers); 5) low pH and 6) stray currents.

The tests for sulfates, chlorides and ammonia indicate that the exposure levels for copper and ductile iron are considered to be negligible. The results of the laboratory testing included in the back of this report, also show pH and resistivity measurements.

The number one factor that causes the most problems for buried copper piping is the "attraction" to copper of stray currents. These currents come from electrical systems of
all kinds including AC and DC currents from the grounding of electrical systems to water piping such as that found in housing units. Electrical current always wants to return to its place of origin in order to complete a circuit. Stray current will travel along the copper pipe and eventually jump-off in its quest to complete the circuit. Where it leaves the pipe, a small amount of metal is taken with it. This continues until a hole develops and a leak is started.

Examination of the sample visually indicates external soil-side corrosion attack. Two failure sites were evident consisting of penetrations of the pipe wall. Deep pitting is also apparent throughout the length of the specimen. These penetrations and pits are indicative of stray current (electrolysis) corrosion.

The recognized standard of soils corrosivity classification based on resistivity is as follows:

<table>
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<th>Ohms-cm</th>
<th>Corrosivity</th>
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<tr>
<td>Below 500</td>
<td>Very corrosive</td>
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<tr>
<td>500 to 1000</td>
<td>Corrosive</td>
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<tr>
<td>1,000 to 2,000</td>
<td>Moderately corrosive</td>
</tr>
<tr>
<td>2,000 to 10,000</td>
<td>Mildly corrosive</td>
</tr>
<tr>
<td>Above 10,000</td>
<td>Progressively less corrosive</td>
</tr>
</tbody>
</table>


The measured resistivity of these soils is recognized as being “Mildly Corrosive” to buried metallic structures such as mild steel, iron and copper. pH values below 9.7 are also recognized as being corrosive to most common metallic construction components including copper, iron and aluminum. Although the native soil is classified as being only “mildly corrosive” from a resistivity standpoint, it must be recognized that the soil is still corrosive and corrosion-to-failure is time weighted.

Copper service piping can be cathodically protected externally at -500 mV or above. This can be accomplished with the installation of an inexpensive sacrificial anode on each service on the City’s side of the meter. The anode will provide a low resistance path so that harmful stray currents can be safely drained from the copper pipe thus further protecting the ductile iron main. Tape wraps or plastic sleeves also can be effective in protecting buried copper. However, these protective coverings must be “holiday” free (no “open” joints or seams; no holes or tears). It is critical to the life of the pipe that the sleeve or tape contains no openings or holes. Penetrations of any kind within these or other protective materials generally leads to accelerated corrosion failure due to the fact that the corrosion attack is concentrated at the location of these penetrations.
Stray currents can be significantly minimized and even mitigated with the installation of sacrificial anodes on the copper services. Unfortunately metal loss cannot be restored, but the corrosion rate on older services can be significantly reduced and may allow for additional service life until failure.

In addition to the soil samples collected and tested, we also collected a sample of the City's standard pipe bedding and backfill material. This material, consisting of cement sand, tested negligible for corrosive chemical constituents and had a very high resistivity classification thus categorizing it as being non-corrosive. Therefore, the material is a very good selection for a pipe bedding and backfill.

We were also able to inspect a recently failed portion of a ductile iron main in Colby Lane. This pipe already had a few failures as evidenced by the repair clamps. Close inspection of one section of the exposed pipe revealed cracking and evidence of galvanic corrosion. We suggested that an additional repair clamp be installed at this location.

As mentioned above, we found that stray AC and DC current spikes on well casings were negligible. During those tests we also recorded the casing-to-soil potentials of the wells. All readings were in the ~500 mV range indicating active corrosion of the steel casings. It is our understanding from discussion with City staff that some wells have lost their column pipes due to corrosion. We were asked to inspect the removed column pipe stores at Well #29. The pipe showed evidence of active corrosion from when it was in service. It was noted that the column pipe was bare steel. We suggest that in the future the City consider having column pipes epoxy lined and coated in order to gain an extended service life.

Failed flange and valve body bolts were also examined. Proper selection of bolting materials for valves and fittings used in buried or submerged environments are very important to the operation of a water system. Commonly used materials must be selected in order to assure availability and cost effectiveness. In many California water agencies the material of choice is stainless steels. Bolts made of these types of steels are very resistant to corrosion attack. However, stainless steel bolts, especially Type 316, present a problem in that bolts and nuts made of this material tend to "stretch" and require re-torquing prior to being placed into service. Additionally, stainless steel bolts and nuts tend to "seize" requiring that they be cut off when removal from service is necessary. These two issues are of great concern to the water operations personnel.

CONCLUSION:

Evidence indicates that the primary cause of the both the copper service and ductile iron pipe failures is the direct connection between the copper service and the iron pipe. And the corrosion attack of both pipes is being promoted by the interconnection of the neutral ground of the electrical systems of residences and commercial establishments to the copper services. Although it appears that the corrosivity of the soil is negligible, it too is a contributing factor in the corrosion cycle. Therefore, recognized accepted standards of
practice should continue to be used when repairing, replacing or installing new buried ductile iron and copper piping systems.

RECOMMENDATIONS:

Ductile Iron Pipe

It is recommended that for new ductile iron piping systems and for the repair of existing systems that the City discontinue the practice of tapping copper services directly into the ductile iron pipe wall but instead make the connection using a full pipe circumference stainless steel clamp with an integral stainless steel service outlet and a full pipe circumference neoprene gasket. This will insure that there is no direct contact between copper and iron thus eliminating the galvanic connection of the two dissimilar metals.

This design will also eliminate the potential stray current path from the neutral electrical grounding of residences etc.

The continued practice of wrapping all ductile iron piping and iron body valves with polyethylene is in keeping with recognized standards of practice. However, we stress that the installation of the wrap must be in strict conformance with AWWA Standard C-105 in that all punctures, tears and seams must be sealed off. Openings in the wrap of any kind generally leads to accelerated corrosion failure due to the fact that the corrosion attack is concentrated at the location of these openings. It is also important that the wrap be sealed off at all service connections as shown on our suggested design standard.

It is further recommended that the City continue to use the cement sand pipe bedding and backfill on all new and repaired ductile iron piping systems. Not only is this material relatively non-corrosive, it provides protection for the polyethylene pipe wrap from damage that can be caused by rocks or other debris that might be in the trench backfill.

Copper Service Piping

Grounding currents must also be eliminated from the copper service in order to stop the corrosion of the services as seen in the examined specimen. Therefore, it is very important that the City continues installing sacrificial anodes on all new and repaired or replaced services.

The City’s current standard water copper service anode includes a 17# magnesium anode. Magnesium is an unstable metal with a high output potential thus anodes made of this metal are self-consuming and therefore have a limited service life, which averages only 7 to 10 years at which time it must be replaced. It is suggested that the City consider changing from magnesium to zinc anodes. Zinc anodes will function very similar to the magnesium but will provide at least twice the service life. Additionally, it is very important that anodes are saturated with water after they are placed in the soil and
prior to backfilling. Anodes are packaged in a cloth bag containing bentonite clay and
calcium sulfate. If this material is not properly wetted the anode may fail to activate. It is
similar to a simple battery that needs an electrolyte to operate. We have included in the
appendix suggested revisions to the City’s standard design for the installation of copper
water services.

Devices such as dielectric couplings at or near the service meter are not recommended
for use as a means for eliminating stray or grounding currents on copper services. These
devices usually contain a dielectric sleeve or washer made of a plastic or phenolic
material that is intended to stop current flow. However, it is recognized that the sleeve or
washer can be and is damaged due to unintentional cross threading or over-tightening
during installation. When the insulating ability of the coupling is compromised in anyway,
the damaging effects of stray currents will prevail.

Bolting Materials

It is recommended that valve body bolts be specified as stainless steel due to the fact
that these bolts are usually the first valve component to corrode and fail. We believe that
the best corrosion resistant material for the manufacture of flange bolts and nuts and
other pipeline fitting components is Type 316 stainless steel. However, in order to assist
the City’s operations staff by reducing bolt “stretch” we suggest the use of 304 stainless
in lieu of the 316 material. The 304 bolts and nuts tend to not “stretch” as much, but they
still may “seize”.

Polyvinyl Chloride (PVC) Pipe

Because corrosive attack can be anticipated in most underground piping systems, PVC
pipe’s immunity to corrosion can provide savings in the form of reduced operating costs
and increased system life. However, due to the fact that PVC is a product of petroleum,
the initial material cost of PVC pipe can be significantly higher than DIP or steel.

Polyvinyl chloride (PVC) pipe is immune to nearly all types of corrosion experienced in
underground piping systems. Since PVC is a non-conductor of electrical currents, both
galvanic and electrochemical effects are non-existent in PVC pipe. PVC suffers no
damage from soil-side corrosion attack. As a result, PVC pipe requires no special
coatings or cathodic protection. However, all ductile or cast iron piping appurtenances,
including fittings and valves, must be at a minimum, wrapped with polyethylene in strict
conformance with AWWA Standard C-105.

Design of a PVC pressure pipe system should indicate the size, type (AWWA C900 and
C905), and the dimension ratio (DR). For C900 pipe the Classes are 100, 150 and 200.
C905 does not have pressure classes, but pressure ratings. Current City practice allows
for pipe sizes 6-inches through 12-inch. These are standard PVC pipe sizes and the OD
of PVC is “iron pipe size”. Therefore, PVC pipe will be compatible with the existing DIP
system. Larger diameter PVC pipe should be considered on a case-by-case basis.
Design for all PVC pipe should have a factor of safety of 2.5 and account for surge pressures.

**C900 PVC PIPE (4 to 12-inch) - AWWA C900 comes in three Pressure Classes - 100, 150, or 200 and conforms to Cast Iron Pipe equivalent outside diameter equivalent dimensions (CI). Each pressure class has a dimension ratio (DR) defined as the diameter divided by wall thickness. The Class of pipe represents the maximum sustained working pressure the pipe should experience. A safety factor of 2.5 is included and an additional surge allowance is provided for C900 pipe assuming a 2-foot per second instantaneous change in velocity (C900 4.7). If surge information is available and it is higher than these values, the subsequent allowable working pressures are reduced and C900 Section 4.7 should be used to calculate Pressure Class.**

**C905 PVC PIPE (14 to 36-inch) - AWWA C905 Pipe does not have Pressure Classes. It does have 6 different dimension ratios (DR), which correspond to a pressure rating (PR) (C905 Table 3). The DR’s vary between sizes and whether CI or IPS dimensions are used (C905 Table 1 and 2). These ratings include a 2.0 safety factor, but unlike C900, no allowance is provided for surge pressures. Also, it is noted that some conditions may warrant higher safety factors (C905 4.6). Design of C905 pipe should be done in accordance with Section 4.6.**

Included in the appendix of this report is a suggested specification for a PVC pressure pipe system. It is recommended that the City consider the use of PVC pipe for future and replacement piping systems in order to reduce losses due to corrosion.

For your convenience, we have included a CD of the suggested standard drawings and PVC pipe specification in the back of the appendix. If you have any questions or would like to discuss these results and recommendations further, please do not hesitate to call.

**RBF Consulting**

[Signature]

John R. Barnes, CCT
Vice President
Corrosion Services
NACE Certification No. 4805

**Reviewed:**

[Signature]

Ted Donigian, PE
Corrosion Engineer
CA CRE #201

Attachments

H:\CDATA\15101349\Reports\Report.doc
STRAY CURRENT INVESTIGATION

The illustrations on the following pages are the actual scope traces recorded during our investigation of possible stray interference currents that may affect the water distribution system. The traces were recorded on a Fluke Model 97 portable oscilloscope. Each trace depicts the voltage amplitude of the structure being measured against a Cu/CuSO₄ reference electrode. The following is an interpretation and summary of each trace.

- Measurable – metal loss over time.
- Moderate – progressively more metal loss in same time period.
- Elevated – significantly more metal loss in same time period.

The Davis 5 trace is the “signature” of the output current of the rectifiers protecting the gas company transmission pipeline system. The remaining traces were recorded at various locations within the City.

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<tr>
<th>Trace No.</th>
<th>Address/Location</th>
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<td>Moderate</td>
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<td>1204 Colby Dr.</td>
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<td>Davis 7</td>
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(1) Water well casing. (2) Stray current pick-up from residence.
LABORATORY REPORT

Prepared For: RBF Consulting-Temecula
40810 County Center Drive, Suite 100
Temecula, CA 92591
Attention: John Barnes

Project: 15-101340

Sampled: 03/21/06-03/22/06
Received: 03/24/06
Issued: 04/04/06 17:23

NELAP #01108CA California ELAP #1197 CSDLAC #10117

The results listed within this laboratory report pertain only to the samples tested in the laboratory. The analyses contained in this report were performed in accordance with the applicable certifications as noted. All soil samples are reported on a wet weight basis unless otherwise noted in the report. This Laboratory Report is confidential and is intended for the sole use of Del Mar Analytical and its client. This report shall not be reproduced, except in full, without written permission from Del Mar Analytical. The Chain of Custody, 1 page, is included and is an integral part of this report. This entire report was reviewed and approved for release.

SAMPLE CROSS REFERENCE

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Del Mar Analytical - Irvine
April A. Robb
Project Manager

IPC2551-Page 1 of 8>
### INORGANICS

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IPC2551  Page 2 of 8
**INORGANICS**

<table>
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<tr>
<th>Sample ID: 1PC2551-03 (2519 ROCKWELL DR - Soil) Reporting Units: mg/m3</th>
<th>Sample Result</th>
<th>Dilution Factor</th>
<th>Date Extracted</th>
<th>Date Analyzed</th>
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**Sample ID: 1PC2551-04 (1284 COLBY) Reporting Units: %**

- **Reported Element:**
  - Sulfate EPA 300.0 6C27059 0.0050 0.00057 1 3/27/2006 3/27/2006 I3
  - pH EPA 9405C 6C24133 0.100 9.07 1 3/24/2006 3/24/2006 I3
  - Sulfate EPA 300.0 6C27059 0.0050 0.0012 1 3/27/2006 3/27/2006 I3

- **Reported Element:**
  - Soluble Sulfate EPA 300.0 6C27059 0.0050 0.0012 1 3/27/2006 3/27/2006 I3
  - pH EPA 9405C 6C24133 0.100 8.83 1 3/24/2006 3/24/2006 I3

---

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### SHORT HOLD TIME DETAIL REPORT

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<tr>
<th>Hold Time (in days)</th>
<th>Date/Time Sampled</th>
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<th>Date/Time Extracted</th>
<th>Date/Time Analyzed</th>
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<td>Sample ID: 3334 CHESAPEAK (IPC2551-01) - Soil</td>
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## METHOD BLANK/QC DATA

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<th>Analyte</th>
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<th>Units</th>
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<td>8.21</td>
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<td>Soluble Sulfate</td>
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<td>%</td>
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<td>48.7</td>
<td>5.0</td>
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<td>Chloride</td>
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IPC2551 <Page 5 of 8>
**METHOD BLANK/QC DATA**

### INORGANICS

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<tr>
<th>Analyte</th>
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DATA QUALIFIERS AND DEFINITIONS

B Sample was received and analyzed past holding time
M2 The MS and/or MSD were below the acceptance limits due to sample matrix interference. See Blank Spike (LCS)
ND Analyte NOT DETECTED at or above the reporting limit or MDL, if MDL is specified.
FPD Relative Percent Difference
Nevada and NELAP provide analyst specific accreditations. Analyte specific information for Del Mar Analytical may be obtained by contacting the laboratory or visiting our website at www.testamericans.com.

<table>
<thead>
<tr>
<th>Method</th>
<th>Matrix</th>
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<td>X</td>
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<td>Soil</td>
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**CHAIN OF CUSTODY FORM**

**Client Name/Address:**
2261 COUNTY CENTRAL DR
PENNSULA, CA 93511

**Project/PO Number:**
1820N-440

**Project Manager:**
JAN BARNES

**Sampler:**
RBE

**Sample Description** | **Sample Mat/Container Type** | **# of Cont** | **Sampling Date** | **Sampling Time** | **Preservatives** | **Phys.** | **Chemical** | **Microbiological** | **Special Instr.**
--- | --- | --- | --- | --- | --- | --- | --- | --- | ---
3714 CHEAPEAK | Soil | 8AL | 1 | 7/13/16 | NONE | X | X | X | X
3754 BACKFILL | Soil | 8AL | 1 | 7/13/16 | | X | X | X | X
2549 ROCKWELL DR | Soil | 8AL | 1 | 7/13/16 | | X | X | X | X
1204 COLBY | Soil | 8AL | 1 | 7/13/16 | | X | X | X | X
305 ANZA | Soil | 8AL | 1 | 7/12/16 | | X | X | X | X

**Received By:**

**Date/Time:**

**Received By:**

**Date/Time:**

**Received By:**

**Date/Time:**

**Turnaround Time** (Check):
- Same day
- 24 hours
- 48 hours
- 5 days
- 72 hours

**Sample Intake (Check):**
- Ice
- Wet

**Payment for services is due within 30 days from the date of invoice. Samples will be disposed of after 30 days.**

**Note:** By relinquishing samples to Del Mar Analytical, client agrees to pay for the services requested on this chain of custody form and any additional analyses performed on this project.
Suggested Revised Standards
NEOPRENE GASKET
DUCTILE IRON PIPE

CORPORATION STOP
GATHER P.E. WRAP AROUND CORP. STOP AND TAPE OVER ALL SEAMS AND OPENINGS IN WRAP

3 STAINLESS STEEL SERVICE OUTLET CLAMP (DRESSER STYLE 360 OR EQUAL)

1 POLYKEN #900 TAPE WRAP.
2 TWO LAYERS OF POLYETHYLENE SLEEVE, 8-MIL MIN. THICKNESS.

36" MIN. COVER
22.5°
5 1/2"
6"

SEE SHT 2

CITY OF DAVIS STANDARD PLAN

WATER SERVICE UP TO 2"
SERVICE TAP OF DUCTILE IRON PIPE

APPROVED _______ 20____
DIRECTOR OF PUBLIC WORKS
R.C.E. No. _______ SHEET _____ OF _____
CLAMP TO COPPER SERVICE LINE BETWEEN MAIN AND METER PER CITY STD. DWG. 101-12

3/4" P.V.C. PIPE CONDUIT WHEN UNDER DRIVEWAY OR OTHER HARDSCAPE

WELL TAMPAID NATIVE SOIL TO 6" ABOVE ANODE

12" NATIVE SOIL

12" SAND (MIN.)

WATER METER BOX

2' MIN

12" DIA AUGERED HOLE

SPICE WIRES WITH "SCOTCHLOK" CONNECTOR SEALING PACK (OR APPROVED EQUAL)

WATER METER IF UNDER DRIVEWAY DRAIN TO ACCESS SERVICE LINE

IF UNDER DRIVEWAY BORE FOR CONDUIT

DRIVEWAY OR GRASS

BACK OF WALK

COPPER WATER SERVICE

WATER MAIN

* INSTALL SACRIFICIAL ANODE CONSISTING OF 18 LB. (70 LB BAGGED) HIGH PURITY ZINC ANODE BAGGED IN A BACKFILL OF CALCIUM, BENTONITE AND GYPSUM, WITH NO.12 SOLID COPPER LEAD WIRE. BURY ANODE IN VERTICAL POSITION. SATURATE ANODE WITH 20 GALLONS OF WATER PRIOR TO BACKFILLING.

---

PLAN VIEW

CITY OF DAVIS STANDARD PLAN

APPROVED WATER SERVICE UP TO 2" ANODE LOCATION

DIRECTOR OF PUBLIC WORKS

R.C.E. No. SHEET 2 OF 2
| Suggested PVC Pipe Specifications |
POLYVINYL CHLORIDE (PVC) PRESSURE PIPELINE

1 General

1.1 Scope

Contractor shall furnish all pipe and fittings together with all material, equipment, and labor and perform all operations necessary to construct water mains and appurtenances as specified, unless otherwise indicated.

1.2 Submittals

Whenever specified by the Construction Drawings or by City, Contractor shall prepare detailed installation or laying drawings for the pipe and fittings showing fittings, appurtenances, and station and elevation for each fitting, each change in alignment or slope, and shall submit these to City for approval in all cases in time sufficient to allow review and approval as hereinabove specified and to accommodate the rate of construction. Contractor shall furnish copies of an Affidavit of Compliance in accordance with Section 1.4, AWWA C-900 and AWWA C-905 (latest). Contractor shall also furnish certified copies of test reports containing results of all physical and chemical tests on pipe and couplings to be furnished showing compliance with AWWA C-900 and AWWA C-905 (latest) as modified herein for polyvinyl chloride pipe.

2 Excavation

2.1 Trenches

Excavation for pipelines and appurtenances shall be open trench to the depth and in the direction necessary for proper construction shown on the Construction Drawings or as otherwise directed by City. Excavation for trenches shall include the removal of all material of any nature at Contractor’s expense for installation of the pipe or appurtenance and shall include either trench sloping or trench shoring, timbering as may be required, and all necessary dewatering. Contractor to obtain any necessary discharge permits required by regulating agencies.

2.2 Limit of Excavation

Trenches shall be excavated not more than 500 feet in advance of pipe laying unless otherwise permitted in writing by City. Trenches shall be adequately shored and braced so that the earth will not slide or settle and so that all existing improvements of any kind will be fully protected from damage. Any damage resulting from lack of adequate shoring and bracing shall be repaired or reconstructed at Contractor’s expense and he shall bear all other expense resulting from such damage. Trenches shall not be left open overnight without permission of City.

2.3 Width of Trench

Unless otherwise shown, all pipeline trenches shall, wherever possible, have vertical sides and a minimum width as possible. Whenever the maximum allowable width of trench is exceeded for
any reason, City may require, at its discretion, that Contractor, at his expense, cradle pipe in Class B concrete or other suitable material approved by City prior to its use.

3.2.4 Excess Excavation

Should the excavation for the pipeline be carried below grade without permission, it shall be refilled to proper grade at Contractor's expense for all labor and material with clean sand or sand and gravel tamped in place to 90% minimum compaction.

2.5 Excavation in Good Soil

The trench shall have a flat or semi-circular bottom conforming to the grade to which the pipe is to be laid. The bottom of trench shall be graded and prepared to provide firm and uniform bearing throughout the entire length of each joint of pipe.

Pipe shall not be laid on earth mounds. It shall be laid so that pipe barrel will bear evenly on the bottom of the trench. Bell holes shall be excavated in the sides and bottom of the trench at pipe joints. They shall be of such size that the process of making joints and inspection can be performed satisfactorily.

2.6 Excavation in Poor Soil

All soft, spongy, or unstable material shall be removed from the bottom of the trench to a depth determined in the field by City and shall be refilled to proper grade, at Contractor's expense, with clean sand or sand and gravel or other suitable material, as approved by City. Bedding material shall be tamped to 90% minimum compaction, graded, and prepared to provide a firm and uniform trench bottom.

2.7 Excavation in Rock

Where rock is encountered, it shall be removed below grade and the trench backfilled with clean sand, sand and gravel or other suitable material, at Contractor's expense, as approved by City, to provide a compacted earth cushion with a thickness under the pipe of not less than four (4) inches. Bedding material shall be tamped to 90% minimum compaction, graded, and prepared to provide a firm and uniform trench bottom.

2.8 Excavated Materials

All material excavated from the trench shall be placed as to offer a minimum of obstruction to traffic. Gutters shall be kept clear or other provisions shall be made for handling street or road drainage. Excess material and material that is not approved by City for use as backfill shall be disposed of elsewhere by Contractor entirely at his own expense unless otherwise permitted by City.

If pipe or other material belonging to City is uncovered or removed from the excavation, all pipe or other material which is salvageable in the opinion of City shall be disposed of, as directed by City. Material not considered to be salvageable shall be disposed of with other excess excavated material at Contractor's expense.
3 Backfill

3.1 Basic Requirements

Backfill shall be as specified by City or in accordance with permits issued by agency having jurisdiction (State, County, City) over rights-of-way in which construction is taking place. Backfill shall be compacted without prior approval of City or other aforementioned agency and in no event shall backfill be placed over pipelines until joints are properly made and inspected.

3.2 Backfill Adjacent to Pipe

Initial backfilling shall be performed as soon as possible after pipe has been laid. Selected backfill material shall be used and it shall consist of clean, loose earth, sand, or gravel free from stones, lumps, vegetable matter, or other unsatisfactory material. It shall have proper moisture content so that specified compaction can be achieved. Said material shall be ¾-inch maximum in size for PVC, and it shall be placed in trench simultaneously on each side of pipe.

3.3 Polyvinyl Chloride Pipe

Selected backfill material of proper moisture content shall be placed in layers approximately four (4) to six (6) inches in depth, each layer being tamped, until the pipe has been covered by at least twelve (12) inches of well compacted material. Said selected backfill shall have a sand-equivalent value of 5.0 and be compacted to a relative density of 90%. Mechanical compacting or water consolidation shall not be used, unless permitted by City, until the pipe has been covered by a minimum of twelve (12) inches of well compacted hand-tamped backfill.

3.4 Backfill Above the Pipe

From the top of the selected backfill to ground surface, the material for backfill shall be free of brush, roots, or organic substances and it shall be free of material exceeding six (6) inches in greatest dimension and in quantity not exceeding 30% of the volume with said coarse materials being distributed throughout finer materials (well graded). All backfill material shall be compacted to a minimum relative compactive of 90% as determined by field compaction tests, unless specified otherwise. Relative compaction shall be determined in accordance with ASTM D-1557 (latest) modified to five-layer curve in lieu of three-layer curve.

Compaction shall be obtained by means of water settlement or tamping, depending on the nature of the material. Sandy, granular soils may be compacted by means of water settlement. Trench to be backfilled by water settlement shall be diked at suitable intervals not to exceed 300 feet. Impounded water shall be of sufficient depth so that earth pushed or shoveled into trench will at all times be falling into water and will be completely saturated. Soils not having a sandy or granular nature shall be backfilled and compacted by either of the following methods:

a. All material shall be placed in layers not exceeding 8 inches in thickness (loose measurement) and each layer compacted to the relative compaction specified by means of hand or pneumatic tampers.

b. All material shall be placed in layers not exceeding 18 inches in thickness (loose measurement) and each layer compacted to the relative compaction specified by the use of a "Hydra-Hammer" tamper or similar equipment.
On steep slopes and other locations where compaction by flooding is not practicable, backfill material shall be compacted by means of either of the above tamping methods.

3.5 Imported Backfill Material

Imported material shall be selected, clean, loose earth, sand, or gravel being one-inch maximum in size. Said material shall be granular and it shall be free of clay, silt, and fine sand. It shall be suitable for compaction with minimum effort. All material imported because of rock or poor soil conditions shall be provided at Contractor’s expense.

3.6 Slurry Backfill - 1 Sack

Where indicated on the plans, slurry backfill shall be placed in pipe trench.

3.7 Finish Backfill

Where pavement is not required, trench backfill shall be brought to grade of existing surface and dressed to provide a firm, stable, and even surface without ruts or irregularities and which is in conformance with grades of existing surface. Where pavement is required, trench backfill shall be placed in accordance with paving requirements.

4 Pipe and Appurtenances

4.1 Pipelines and appurtenances shall be constructed in accordance with Construction Drawings, Standard Drawings, Specifications, or as specified by City.

4.2 Pipeline Valves and Appurtenances

Pipeline valves at pipeline intersections shall be connected directly to pipeline intersection fitting (cross or tee) and all mainline or side outlet valves shall be located three feet minimum from any curb facing unless specified otherwise. Valves shall not be placed under curb or gutter or in parkway unless approved by City. All valves will be installed with vitaulic couplings, steel pipe only. All appurtenances, including but not limited to air valve installations, blowoff installations, and related facilities such as fire hydrants, fire services, and water services shall not be installed within five feet of curb returns, curb depressions, and driveway approaches, or in an inaccessible location or locations where interferences may restrict operation of facility unless specified otherwise.

4.3 Pipeline Length

All pipeline lengths noted by the Construction Drawings or specified otherwise or referenced shall mean net horizontal constructed length and said length shall extend through all fittings and appurtenances including bends, outlets, tees, flanges, and valves unless otherwise specified. Contractor shall provide all pipe necessary to accommodate any vertical alignment of the pipeline and said pipe shall be represented by the net horizontal constructed length. Payment for pipeline shall be based on net horizontal length.
4.4 Pipeline Alignment

All pipelines shall be constructed with no basic variation in horizontal alignment as shown by the Construction Drawings. Pipelines shall be constructed parallel with centerlines of streets or rights-of-way and appurtenances shall be constructed perpendicular thereto unless the Construction Drawings specify otherwise. Contractor will be permitted, subject to approval of City, to construct pipelines with variations in vertical alignment as shown by the Drawings, in all non-critical areas, in which case Contractor will be permitted to make full use of pulled joints, short joints, and elbows to vary the pipelines from the profiles shown. Critical areas shall include areas of pipeline connections, underground interferences, and minimal pipeline cover. City will not approve variation in vertical alignment until the proposed revised alignment has been determined to be proper and modifications are found to be in order.

4.5 Pipeline Cover

Pipeline cover as shown by the Construction Drawings is hereby defined as design cover over the top of pipeline. Should field conditions determined at time of construction staking show that pipe grade changes are required to provide design cover, City reserves the right to direct said changes in pipeline grade and Contractor shall construct pipeline accordingly. Pipeline cover shall not be less than 42 inches from top of pipe to ground surface over pipeline. Where ground surface elevation over pipeline has been established and where actual ground surface is greater, pipeline cover shall be referenced to the established ground surface elevation and not the actual ground surface.

4.6 Thrust Protection

All tees, angles, etc. shall be protected from vertical and horizontal movement. The plans and specifications shall indicate the amount and type of thrust protection. Thrust protection shall consist of concrete thrust blocks, refer to City of Davis Standard Plan No. 101-2, “Thrust Block Bearing Area”, or thrust restraint fittings, as approved by the City.

5 Pipe Materials

5.1 General

All pipe furnished shall be manufactured by an organization which has had not less than ten (10) years successful experience in the manufacture of the type of pipe specified. City shall at all times have the right to inspect all work and materials in the course of manufacture. Manufacturer shall furnish City reasonable facility for obtaining such information as he may desire regarding the progress and manner of the work and the character and quality of materials used.

5.2 Polyvinyl Chloride Pipe

5.2.1 Scope

Polyvinyl chloride pipe furnished under these Specifications shall conform to AWWA Standard Specification C-900 and C-905 (latest) as modified herein, by the Construction Drawings, or by City.
5.2.2 Pipe

All pipe furnished shall conform to AWWA C-900 and AWWA C-905 (latest) and shall also conform to the following additional requirements.

a. Pipe, including standard, random, and special short lengths, shall be minimum Class 150 with cast iron pipe equivalent outside diameter unless specified otherwise.

b. Standard lengths of pipe shall have a nominal length of 20 feet, 0 inches, plus or minus 1 inch. Random lengths of pipe shall not be less than 10 feet, 0 inches, plus or minus 1 inch. Special short lengths, minimum 5 feet, 0 inches, shall only be furnished where needed to accommodate specified fitting.

c. Pipe, including standard, random, and special short lengths, shall have sufficient strength to withstand an internal hydrostatic pressure of four times the rated operating pressure for its class.

d. PVC pipe shall be color-dyed for the following types of applications:
   1. Potable Water: white or blue
   2. Reclaimed Water: purple

PVC pipe shall be stamped according to the following types of applications: AWWA PVC C-900 (905), CL 150 (200, 165, 235), "Water" ("Reclaimed") Main, etc.

5.2.3 Fittings

All fittings shall be ductile iron and shall conform to AWWA C110 or C153. Fittings shall be designed and manufactured to fit cast iron pipe equivalent outside diameter and fittings shall be cement mortar-lined per AWWA C104, standard thickness. Fittings to be included shall be as listed in the general catalog of the ductile iron fitting manufacturer. All fittings shall be wrapped in 8 mil. polyethylene per AWWA C105.

All joint gaskets shall be Tyler Grip-Tite or Trinity (Tyton).

5.2.4 Testing

All pipe, including standard, random, and special short lengths, shall be tested in the United States in accordance with Section 3.3, AWWA C-900 (latest).

6 Installation

6.1 Loading, Transporting, and Unloading

After the pipe has been manufactured and tested, it shall be loaded on rubber-tired vehicles, adequately supported and chocked to prevent any damage during transportation, and delivered job site. During the unloading and stringing operations, the pipe shall be moved in such a manner as to prevent injury to the pipe. Unloading shall be accomplished in a workmanlike manner as directed by the City. The Contractor shall use double straps, placed equal distance from each
other and the ends of the pipe, to unload the pipe. Under no circumstances are pipe sections to be dropped or bumped in handling.

6.2 Defective or Damaged Material

The pipe shall be carefully inspected for defects. Any pipe found to be defective in workmanship or material or so damaged as to make repair and use impossible shall be rejected and removed from the job site. In the event a portion of a length of pipe is damaged, it shall be replaced with an undamaged section. Contractor shall be responsible for any and all damage to material and he shall stand the expense of repairing or replacing same. Proper precautions shall be taken to assure that the rubber rings are protected from oxidation or undue deterioration.

6.3 Polyvinyl Chloride Pipe

All pipe shall be laid true to line and grade and at the locations shown by the Construction Drawings. Polyvinyl chloride pipe shall be installed in accordance with applicable provisions of AWWA C-903 or AWWA C-605 (latest), AWWA Manual No. M23, and manufacturer's directions, all as modified herein. Bell ends shall be placed uphill unless otherwise permitted. Bell ends shall always be placed uphill on steep slopes (10% or more).

The trench bottom shall be constructed to provide a firm, stable uniform support for the full length of the pipe. The minimum clear width of unsheeted or unshored trench measured at the springline of the pipe shall be 18 inches or 1 foot greater than the outside diameter of the pipe, whichever is greater. The maximum clear width of trench at top of the pipe shall not exceed the outside diameter of the pipe plus 2 feet.

After pipe has been set in trench, exterior of spigot end and interior of bell end shall be thoroughly cleaned. A lubricant as recommended by the pipe manufacturer and as approved by City shall be applied to the rubber gasket. The lubricant shall be water soluble, nontoxic, shall impart no objectionable taste or odor to the water, shall have no deteriorating effects on the rubber gaskets, and shall not support growth of bacteria. Excess lubricant shall be removed. The ends shall be aligned and the spigot end of the pipe pushed into the bell.

A pipe locator wire shall be installed along the top of the pipe. The locator wire shall be No. 14-gage UF coated solid copper and shall be tied in place by No. 14 AWS coated copper ties or plastic tape with a minimum of two ties per joint. Locator wire shall be color coded: white - potable water; purple - reclaimed water; green - sewer force main.

As the work progresses, a pipe cleaning tool as approved by City shall be drawn through the pipe to remove dirt, rocks, or other similar foreign material.

At the end of each day's work, all openings in the pipeline shall be plugged with watertight expandable plugs or approved equal.

Pipe manufacturer and fitting manufacturer shall have free access to the work during installation.
7 Testing

7.1 General

Contractor shall furnish all equipment, labor and material, exclusive of water, for testing and disinfecting the pipelines. Water used for testing will be furnished by City, but Contractor shall provide the necessary means to deliver water from the nearest available connection to the points of test. All tests of pressure piping shall be made in the presence of the City. All pipelines shall be thoroughly flushed with water prior to testing. Contractor shall test the pipelines in sections after backfilling operations are completed and prior to placement of permanent surface. Permanent surfacing at intersections may be done prior to testing.

7.2 Filling

The pipeline shall be isolated by placing temporary bulkheads in the pipe at the point of connection to the existing system. The pipeline shall slowly be filled with water. All air valves shall be open during the filling. During this period, bulkheads, valves, and connections shall be examined for leaks. If any are found, they shall be stopped or in case of leakage through valves in the main line or through bulkheads, provisions shall be made for measuring such leakage during the test.

7.3 Testing

The test shall consist of holding the test pressure on each section of line for a period of four hours. The test pressure at the lowest point in the line, or section of line, shall be 10 percent higher than the minimum pipeline design pressure. The water necessary to maintain this pressure shall be measured through a meter or by other means satisfactory to City. The leakage shall be considered the amount of water entering the pipeline during the test, less the measured leakage through valves and bulkheads. The leakage shall not exceed the quantity specified in AWWA Manual No. M23.

Any noticeable leaks shall be stopped and any defective pipe or equipment shall be replaced with new pipe or equipment until the leakage is reduced to the specified quantity. After the pipe has met all test requirements specified herein, the entire pipeline shall be filled with water and so maintained until the completion of the contract unless otherwise ordered by City.

8 Disinfection of Pipeline and Appurtenances

Contractor shall furnish all equipment, labor, and materials for the proper disinfection of all pipelines and appurtenances. Contractor may disinfect pipelines and appurtenances either before or after they are subjected to hydrostatic and leakage tests and Contractor shall be completely responsible for providing an adequately disinfected pipeline before it shall be accepted. If Contractor elects to disinfect before hydrostatic and leakage tests, he shall be required to again disinfect all or portions of tested pipeline if repairs or replacements are found necessary after said tests.

The method of disinfection shall conform to provisions of AWWA-C501 (latest). The chlorinating agent, normally liquid chlorine (gas under standard conditions), shall be applied as prescribed by City and at locations selected by or designated by City. The concentration of the dosage applied to the water within the pipeline shall be at least 50 ppm and it shall not exceed 200 ppm.
Liquid or gas chlorine shall be used for disinfection solutions, unless specified otherwise or special permission is granted by City to use calcium hypochlorite granules, sodium hypochlorite solutions or calcium hypochlorite tablets. Said permission shall be obtained prior to disinfection.

Chlorinated water must be retained in the pipeline long enough to destroy all non-spore-forming bacteria. Said period shall be at least 24 hours. After the chlorine-treated water has been retained for the required time, the chlorine residual at the pipe extremities and at other representative locations shall be at least 25 ppm.

Following chlorination, Contractor shall flush all pipelines and appurtenances in the manner and with the procedure prescribed by City. Flushing shall continue until all chlorine, debris, and foreign materials have been removed from pipelines and appurtenances. Contractor is responsible and liable for disposal of chlorinated water. If so directed by City, Contractor shall remove portions of certain appurtenances such as air valve installations, blowoff installations, and service installations in order to accomplish complete flushing and replace same without adversely affecting disinfected pipelines and appurtenances. Should the initial treatment fail to produce satisfactory disinfection of the pipeline as evidenced by chlorine residual and bacteriological analysis, the disinfection procedure shall be repeated until acceptable results are obtained.

Chlorine residual and bacteriological analysis tests shall be arranged with the City and paid for by the City. If the initial tests fail, the Contractor shall pay for all additional tests.

Following disinfection, pipelines and appurtenances shall remain isolated from any operational water system facilities until evidence has been submitted to City demonstrating that said pipelines and appurtenances have been adequately and properly disinfected. Said evidence shall consist of the aforementioned Affidavits of Compliance together with said bacteriological test results. Normally, said pipelines and appurtenances shall be isolated for at least 48 hours, longer if so determined by City.

9 Connection to Existing Facilities

Following the completion of pipeline pressure testing, disinfection, and acceptance by City, the Contractor shall connect the new facilities into the existing facilities. The connections shall be made by a "hot-tap" into the existing facilities, or by a system shutdown and connecting into a "dry" facility.

9.1 Hot-tap Connection

At the City's discretion, the Contractor will be allowed to "hot-tap" connect into the fully pressurized City facility. "Hot-tap" connections will be allowed on existing DIP, ACP, and CML/SC Steel Cylinder pipes with a maximum branch pipe diameter to trunk pipe diameter ratio of 75%. No "hot-tap" connections will be allowed on pre-tensioned, rod wrapped steel pipe. Approved, tees, tapping saddles, pipe flanged nipples, valves, etc. shall be in place prior to the "hot-tap" connection. The minimum distance between "hot-tap" connections is five (5) feet for DIP and steel pipe. Only one "hot-tap" connection is allowed for each joint of PVC and ACP pipe. The Contractor or his subcontractor performing the "hot-tap" connection shall have a minimum five (5) years experience in making these types of connections. The tapping machine shall be in good working condition and all bits and cutters shall be sharpened prior to the "hot-tap". The Contractor shall supply all labor, materials, and equipment necessary to connect to the existing
system including pumps, lights, barricades, and any other equipment required to complete the connection in a safe and timely manner.

9.2 System Shutdown Connection

The Contractor shall supply the City with a three-week written notice requesting a system shutdown according to the Plans and Specifications. All connections or tie-ins to the existing facilities requiring system shutdown and draining of the existing facilities shall be done at night or as approved by City. The City shall operate all valves required to shut the system down to drain the City's facilities. The Contractor is responsible to drain and de-water the existing pipeline after the City has shut the system down prior to making the tie-in. The Contractor shall supply all labor, materials, and equipment necessary to connect to the existing system including pumps, lights, barricades, and any other equipment required to complete the connection in a safe and timely manner. The Contractor shall be solely responsible for obtaining all de-watering permits and the cleanup associated with the de-watering operation.