Levee District No. 1 of Sutter County
Lower Feather River Setback Levee at Star Bend

Tudor Mutual Water Company
Star Bend Pumping Plant
Basis of Design Report for System Modifications

September 2010

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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INTRODUCTION

In 2005, Levee District No. 1 (LD 1) contracted with Wood Rodgers, Inc. to prepare a feasibility study for a new setback levee at the right bank of the Feather River at Star Bend. The new levee was designed to provide substantial improvements to the hydraulics of the Feather River during high water events and to correct a levee segment with a significant history of seepage problems. The project also provided acreage to enhance existing riparian habitat located waterward of the new levee at the O'Connor Lakes Unit of the California Department of Fish and Game. The alignment of the new setback levee is shown on Figure 1. The project was substantially completed in December 2009.

To accommodate the project, the existing irrigation facilities associated with the Tudor Mutual Water Company (TMWC) Star Bend Pumping Plant required modification. The Star Bend Pumping Plant is located approximately at River Mile 18 on the Feather River. Since the new levee was relocated a substantial distance away from the pumping plant, new pipelines, a distribution box, and other facilities were required to deliver the flow from the pumping plant to the landward side of the new setback levee. The intent of the design was to convey this water over the new setback levee without substantially modifying the existing pumping station.

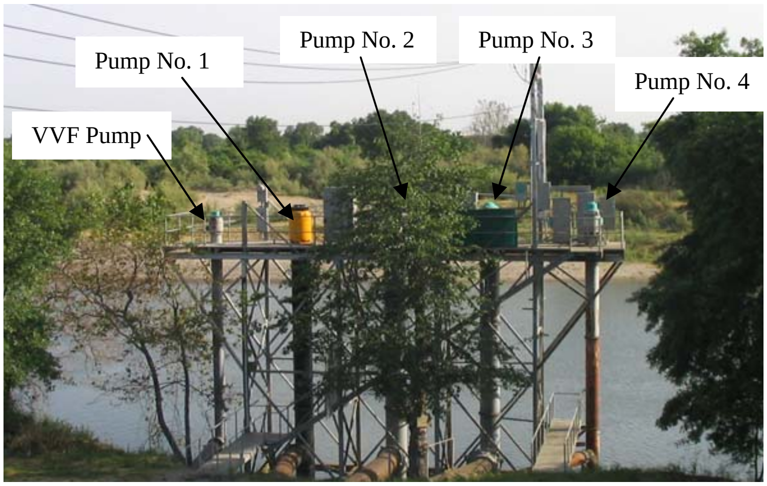
This Basis of Design report outlines information and criteria supporting the original system modification design, incorporated as part of the levee improvement project, and the design of supplemental features added after construction to enhance system performance with respect to flow variation and overall flow capacity.

EXISTING PUMPING SYSTEM

The Star Bend Pumping Plant consists of five vertical turbine-type pumps on a steel platform structure at the right bank of the Feather River. Four of the pumps belong to TMWC and one pump belongs to Volcano Vista Farms (VVF). Photograph 1 illustrates the pumping plant configuration, looking east from the west bank of the Feather River near River Mile 18. The photograph is labeled to show the naming convention of the various pumps as discussed within this report.

Table 1 provides information that was gathered at the inception of the project for each of the pumps based upon their nameplate data. Additional information was obtained from a local pump distributor with access to the original pump manufacturer's files. The original pump drawings and design curves obtained for the pumps are included in Appendix A. Head versus flow curves representing current pump performance were developed by Mr. Kit Burton, P.E., on behalf of LD 1 and TMWC and are included as Appendix B.

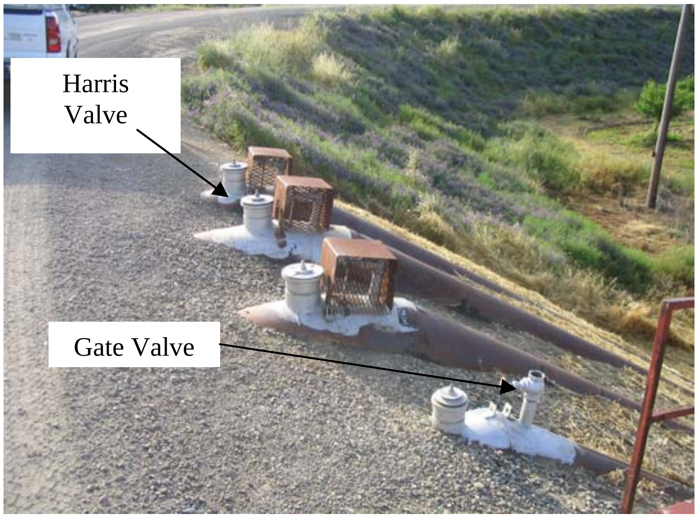
Photograph 1 – TMWC Star Bend Pumping Plant



The pump station was originally constructed in the 1950's. The original design drawing for the layout of the pumping plant and its discharge pipelines is included as Figure 2. Under the existing pump station configuration, each pump discharge pipe delivered flow over the levee in its own pipeline. These pump discharge lines were 24 inches to 26 inches in diameter. An exception to this configuration is the discharge lines for Pump No. 3 and Pump No. 4, which were coupled together into a single 26-inch pipeline. The VVF pump discharges into its own, 16-inch-diameter pipeline, which entered its own standpipe structure on the landside of the existing levee. A schematic diagram of the pre-project and modified system configurations is included as Figure 3.

Each of the pump discharge pipes, at the levee landside top of slope, was equipped with a Harris brand vacuum assist valve and a small gate valve. Photograph No. 2 shows the arrangement of these valves at the crown of the pipelines. Harris valves are designed to evacuate air on pump start-up and close once full pipe flow is achieved. This produces a siphon condition within the pipeline, reducing the total static head the pump is required to overcome. The mechanisms of siphon operation are further described below under *Basis of Design for Pump Discharge and Levee Crossing Pipelines*. The Harris valve also automatically opens once the pump shuts down, re-introducing air into the pipeline to break the siphon and prevent vacuum forces from damaging the pipe. The 2-inch gate valves were installed downstream of the Harris valves by TMWC and VVF as a means to adjust the flow in each pipeline to meet downstream demand. These valves operated by permitting air to flow into the pipeline, thus creating additional friction loss and reducing the flow from the pump. Another method employed by TMWC to adjust flow has been to open a valve installed on the column of Pump No. 3 and Pump No. 4, which returns a portion of the flow back to the river. It is noted that these methods of regulating and reducing flows introduce significant inefficiencies into the system and result in higher pumping costs. Due to the limited information regarding pre-project operational records, no attempt was made to quantify these inefficiencies.

Photograph 2 – Pipeline Valves at Landside Levee Top of Slope



All pipelines, with the exception of the VVF pipeline, discharged into a large distribution box at the landside of the existing levee (Photograph 3). The box was approximately 220 feet from the discharge elbows at the pump station. The top of the existing distribution box was surveyed and determined to be at an elevation of 59.65 feet (NGVD 29). Discussions with the operator indicated the normal water surface elevation during the peak of the irrigation season was about nine feet down from the top of the box, or approximately 50.65 feet (NGVD 29). A survey of the darkened high water mark in the box indicated an elevation of approximately 52.0 feet. This was identified as the most likely operating elevation within the distribution box. It is noted, however, that depending upon downstream water demand, the operator raises or lowers the water surface elevation in the box to suit the demand.

Photograph 3 – Existing Distribution Box at Landside Levee Toe

Downstream of the distribution box, an existing 30-inch pipe carried flow northwest and then west at Star Bend Road. A 42-inch pipe carried flow south, then west at Tudor Road. The routing of these original pipelines is also shown on Figure 1. All existing pipelines downstream of the distribution box were unreinforced cast-in-place concrete pipe (CIPCP).

To deliver the appropriate quantity of flow to either the 42-inch or 30-inch pipeline, the operator would visually monitor float gages at existing standpipes located several hundred feet downstream of the distribution box. Operational knowledge of the system informed the operator what water level in the standpipe would be adequate to meet downstream demand.

The original design drawing showing the pump station and discharge lines is included as Figure 2. A schematic layout of the original pump station layout and the new pump station layout is included as Figure 3. A plot of the pre-project pump curves and post-project system curve is included as Figure 4.

REFERENCES

The following references were used in formulating the design of the new project facilities relating to the Star Bend Pump Station.

Hydraulic Design References

1. Handbook of Hydraulics, Brater & King, fifth edition.
2. Fluid Mechanics, Victor L. Streeter, third edition.

Levee Pipeline Crossing References

1. Design and Construction of Levees, Engineering Manual EM 1110-2-1901, U.S. Army Corps of Engineers, 30 September 1986; 30 April 1993 (Change 1).
2. Central Valley Flood Protection Board (CFVPB) Standards: California Code of Regulations (CCR), Title 23, Division 1, Article 8 (Section 123, Pipelines, Conduits, and Utility Lines).
3. Code of Federal Regulation, “Mapping of Areas Protected by Levee Systems,” 44CFR65.10, Federal Emergency Management Agency, Department of Homeland Security, amended August 25, 1986.

Structural Design References

1. ACI 318-05, Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute.
2. 2003 International Building Code, International Code Council.

Electrical Design Reference

1. 2005 National Electrical Code (NEC), National Fire Protection Association (NFPA), 2005.

2. IEEE Standard 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, Institute of Electrical and Electronics Engineers.

Other References

1. Cross Section of the Levee of Levee District No. 1 of Sutter County, California, Showing Proposed Pipes to be Installed for Tudor Mutual Water Company, dated August 15, 1955, Edward von Geldern, Civil Engineer.

2. Service Area Map for Tudor Mutual Water Company, Sutter County, CA, May 26, 1994, Edward von Geldern Engineering Company.

3. Byron Jackson Pump Company Pump Dimensional Drawings and Performance Curves (Appendix A).

4. Memorandum - Pump and Pipeline Capacity Testing at Star Bend (Tudor Mutual Water Company Pumps), May 14, 2010, Wood Rodgers, Inc.

5. Draft Preliminary Report, "Comparison of Water Delivery Pre- and Post-Project at Star Bend, July 8, 2010," Burton, Kit R.

6. Analysis of New Irrigation System, Tudor Mutual Water Co. at Star Bend, August, 6, 2010, Burton, Kit R.

7. Head Versus Capacity Curves for TMWC Pumps 1 & 3, 2, and 4, dated June 2010, Burton, Kit R. (Appendix B).

BASIS OF DESIGN FOR NEW SYSTEM COMPONENTS

The new pump discharge and levee crossing pipelines were designed to convey the existing pump flow combinations from the pump station without increasing the Total Dynamic Head (TDH) of the system. This was necessary to ensure the new system operated with at least the pre-project flow capability of the existing system. TDH is defined as the summation of the static head (lift), friction loss, and all minor losses associated with pipeline bends, changes in diameter, valves, or other equipment. The determination of TDH for both the existing irrigation system and the new system is summarized in Table 2.

It is noted that the pipelines are also designed to operate as siphons. This means that once the system is primed (all air is removed), a siphon condition is developed such that the static head is reduced from a point coincident with the top of the levee crossing to a point coincident with the operating water surface elevation in the distribution box. These two elevations are typically 15 to 20 feet apart, with the water level in the distribution box being lower. Air release valves specified in the original design, and those added later to the system, were necessary to assist with this requirement. During system start-up, it was determined that additional means to more completely remove entrained air from the system were necessary. To accomplish this, a vacuum pumping system was designed as further discussed below under *Design of Levee Crossing Pipelines* and *Design of Vacuum Pumping System*.

Determination of Static Head for Existing Pumping System

The static head for the existing system was determined based upon existing information and field surveys performed during preliminary design. A water surface measured on August 12, 1955, is shown on Figure 2 and labeled 30.56 feet (USED datum). This value is also indicated on the manufacturer's pump drawings as the minimum water level, and is taken to have been the design water surface elevation for the existing system. This water levee is equivalent to a NGVD 29 datum elevation of 27.56 feet. It is noted that the stage in the Feather River is variable over the course of the irrigation season, depending upon releases made at Oroville Reservoir, typically varying between 3 and 5 feet.

Based upon this design river water surface elevation (27.56 feet) and the surveyed information from the distribution box noted above (52.0 feet), a total static head of approximately 25.0 feet was assumed for the existing system. During start-up, prior to the establishment of a siphon, it was necessary for the pumps to lift water to an elevation above the invert of the pipes where they crossed the levee. This elevation is reported as 64.0 feet (NGVD 29) on Figure 2. The total static lift during start-up is therefore approximately 36.5 feet. It is noted to establish a siphon, the pumps must deliver water to an elevation corresponding to the top of the pipes, so that the pipes are flowing full.

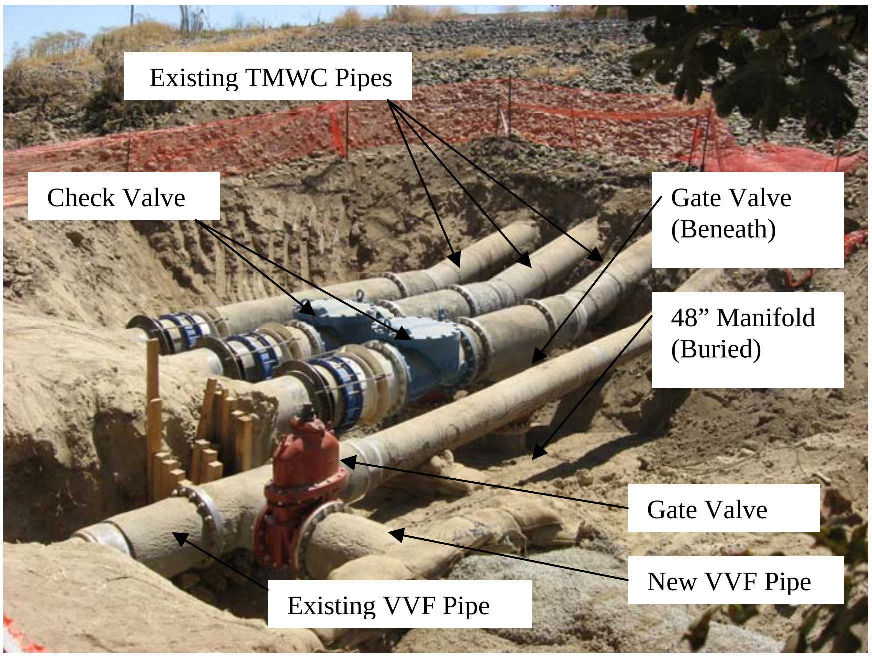
Design of Manifold and Conveyance Pipelines

All TMWC discharge pipes from the existing pump station were designed to be combined into a single pipeline to convey the flow to the new setback levee. A single 48-inch reinforced concrete cylinder pipe (RCCP) was designed to carry the TMWC flow, and a smaller 24-inch reinforced concrete pipe was designed to carry the VVF flow. The length of these pipelines is approximately 1,600 feet. A 48-inch manifold pipe was constructed to connect to the existing TMWC pump discharge lines where they enter the embankment just downstream of the pump station. As the irrigation season overlapped the available construction window, it was necessary to install the manifold and conveyance pipeline in such a way that these components could be constructed while the existing pipes remained in operation. This was accomplished by installing the manifold pipe beneath the existing pipelines.

Air relief valves, located in buried utility boxes, are provided on the conveyance pipeline at the manifold location. These utility boxes have lids that are designed to permit the valves within the boxes to expel or accept air into the pipeline.

A gate valve was installed between the pump discharge and the manifold pipe to allow water to flow into the manifold once the downstream facilities were constructed. A separate connection was made between the new VVF pipeline and the existing pipeline, and a gate valve was installed at that location. At the conclusion of the irrigation season, the existing pipes were cut and blind flanges were installed at their points of termination. New check valves were installed on the outfall pipes for Pump No. 1 and Pump No. 2, since these pipes were not previously connected to other pump discharge lines. The valves prevent water from flowing back through the adjacent pump discharge line when the adjacent pump is not in operation. Photograph 4 shows the connection between the discharge pipes, manifold, and conveyance pipelines.

Photograph 4 – Connection between Pump Discharge Lines, Manifold, and Conveyance Pipelines



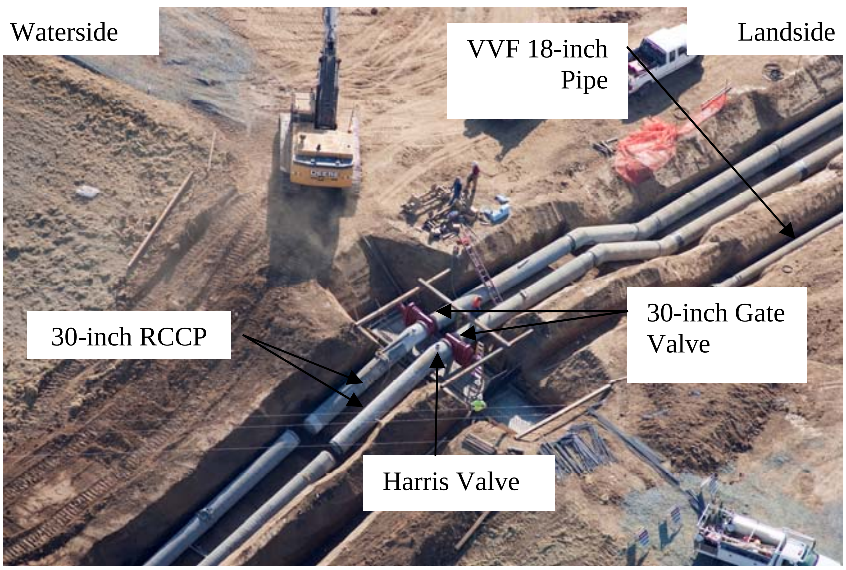
The new 48-inch pipe is a concrete cylinder pipe. It conveys flow from the manifold to a point of bifurcation at the levee waterside toe, opposite the new distribution box, near Star Bend Road. In order to prevent washout of the backfill of this pipeline by the river during high flow events, it was backfilled with controlled low-strength material.

Design of Levee Crossing Pipelines

At the base of the new levee, the 48-inch RCCP is split into two 48-inch pipes, each reducing to a diameter of 30 inches. The 30-inch pipes are mortar-lined and coated welded steel pipe. The pipe segments are joined by full-penetration welds in accordance with the Central Valley Flood Protection Board (CVFPB) requirements. Photograph 5 shows the pipeline levee crossings. Both pipes convey flow over the levee and into the distribution box. These pipelines are designed to: (1) minimize additional TDH as described above; (2) maintain a minimum velocity to assist in expelling air within the pipeline; (3) comply with all CVFPB, U.S. Army Corps of

Engineers, and Federal Emergency Management Agency standards as outlined in the Levee Design References noted above; and (4) limit localized "ramping" of the levee crown embankment over the pipes to achieve the desired pipe cover. It is noted that without the assistance of a vacuum pump system, one of the pipes will fill, close its Harris valve, and operate at a lower pressure sooner then the second pipe. The pipe that achieves this condition first is likely a function of the adjustment of each Harris valve. This has the effect of introducing a preferential flow path for water through one of the pipes. Testing has indicated that once this condition is established, without a means to lower the pressure of the second pipe, it is likely all of the flow will travel through one of the two 30-inch pipes. The vacuum pump system, described below, is designed to alleviate this problem.

Photograph 5 – Levee Pipeline Crossing



The VVF pipeline is reduced to an 18-inch mortar-lined and coated welded steel pipe over the levee. It is not equipped with a vacuum pump system.

A 30-inch resilient seat gate valve is required as noted above in Reference No. 2 of the Levee Pipeline Crossing References, and is installed at the waterside top of slope on each pipeline. The depth, separation, pipe type, and backfill specifications for these pipelines are designed in accordance with Reference Nos. 1, 2, and 3 of the Levee Pipeline Crossing References.

A Harris valve is also installed at the waterside top of slope and is necessary to assist in generating a siphon condition within the pipelines. These valves are of the same design as the original installation and are sized in accordance with the manufacturer's recommendations.

The VVF pipeline contains an 18-inch gate valve at the levee top and its own Harris valve.

The TMWC pipelines also contain a 2-inch gate valve at the landside levee top of slope. These valves were originally intended to allow the operator flexibility in varying flow by admitting air into the system as was done with the existing system. These small gate valves are not as effective in adjusting flow within the system as the Variable Frequency Drive (VFD) system. In fact, they should not be used for this purpose as they will result in the vacuum pump system (described below) working to compensate for their influence on flow.

The 30-inch gate valves, Harris valves, and vacuum pump system are contained in a reinforced concrete vault at the waterside levee top of slope. Two manholes provide access to the valves and are located on the waterside edge of the operating road. One of the manhole lids is designed to be open-grated so that air expelled from the Harris valves can be released to the atmosphere.

Design of Distribution Box

The TMWC pipelines enter the distribution box at elevation 53.0 feet and are outfitted with a 90 degree, 30-inch elbow, by which the flow is piped to the base of the distribution box. Photograph 6 shows an exterior view of the box prior to the placement of fill around the structure. This structure is designed to be fully buried.

Photograph 6 – New Distribution Box

The distribution box is a cast-in-place concrete structure. There are two slide gates that can be operated by a handwheel equipped with a gear reducer to turn water out into either or both of the 42-inch or 30-inch downstream pipelines. There are two reinforced concrete pipe (RCP) standpipes equipped with water level float gages downstream of the distribution box, one on each of the downstream pipelines. Similar to the method of operation for the old system, the operator can visually monitor the water level in the downstream standpipes, adjust the number of pumps running, and adjust the position of the slide gates to target a water level in the standpipe.

The structure also contains an automatic pump shut-off switch to prevent overflow of the distribution box and a spillway section at the top of the box, should the shut-off switch fail.

There is a separate box for the VVF system, which essentially acts as an air relief facility and manhole access point. There are no gates installed at the VVF distribution box.

A remote pump start and stop control panel is provided at the distribution box area. After construction, a new 120/240V, 3-phase, 100-amp service panel was provided near the distribution box area to serve the vacuum pump system described below. This electrical service is an extension of the PG&E service which provides electrical power to the LD 1 relief well pump station located at the end of Star Bend Road.

<u>Design of Irrigation Pipelines</u>

The irrigation pipelines were designed to convey flow from the new distribution box to the existing pipe network landward of the new setback levee. In essence, the project increased the length of the run between the distribution box and the irrigation system to the south (the 42-inch pipeline), and decreased the length of the run between the distribution box and the irrigation system to the north (the 30-inch pipeline). To confirm the longer pipe run would not adversely impact system hydraulics, the additional friction associated with the length of pipe was compared with the reduction in friction obtained by replacing the CIPCP with new, smoother, RCP. The Manning equation was used to determine the friction loss in both the existing and new pipeline for the same flow. The Manning equation is as follows:

$$Q = (1.49/n)*A*R^{2/3}*S^{1/2}$$

Where:
Q = flow (in cfs)
“n” = unitless Manning friction factor
A = area of the pipe (in feet)
R = hydraulic radius (in feet)
S = slope of the friction gradient (in feet per foot)

A friction factor of .016 was selected for the existing CIPCP and 0.012 was selected for the new RCP. The existing 42-inch CIPCP was approximately 2,260 feet long and with both Pump No. 1 and Pump No. 4 running through the pipe, friction losses are equivalent to approximately 1.7 feet. The new 42-inch RCP pipeline is approximately 2,855 feet long and under the same flow, experiences a loss of approximately 1.2 feet. For lower flows, the reduction in friction loss is less significant, but in all cases the loss in the new system is less than that of the old system. Therefore, it was determined that no increase in the pipe size was necessary.

<u>Design of Vacuum Pump System</u>

The purpose of the vacuum pump system is to ensure that the 30-inch pipelines crossing over the levee are primed and flowing full, and the hydraulic grade line of the system at the levee crown is approximately coincident with the water surface elevation in the distribution box. This will ensure that fully efficient siphon-assisted flow will be developed in the pipelines and the static lift required of the pumps will be minimized.

The vacuum pump system consists of an oil-less rotary vane vacuum pump installed within the valve vault located at the levee waterside top of slope. The pump operates on 240VAC power and is connected to a control panel located within the gated area of the distribution box. The pump is mounted on a 60-gallon vertical air receiver tank, which separates and stores water condensed from the evacuated air. One-inch-diameter pipes attach the vacuum pump to each of the 30-inch levee crossing pipelines at their high point over the levee crown. Electrically-operated solenoid valves are actuated by the vacuum pump control panel when pressure in the pipeline is higher than a specified value, signifying a pumping condition. The pressure set point for the call to open the solenoid valves can be set locally by the operator. It is noted that operating the vacuum system to control flow is not as efficient as using the VFD system for this purpose. The target value for the vacuum pump to reduce pipeline pressure is equal to the difference between the gage reading and the elevation at the sensor's connection point to the pipelines, and the water surface elevation in the distribution box. The water surface elevation in the distribution box is determined electronically by a capacitive probe level transmitter installed at the distribution box. During the peak of the 2010 irrigation season, the level in the distribution box was typically set by the operator to be between elevation 45 feet and 48 feet (NGVD 29). A band of target pressures is allowed within the vacuum pump control panel such that frequent starts and stops of the vacuum pump system are avoided. It is critical to ensure that the Harris valves are properly adjusted and not leaking air into the pipelines once priming is completed. Ensuring that the valves are not leaking air will minimize the amount of time the vacuum pump system is required to operate.

The vacuum pump specified for the project is capable of drawing air out of the system at an average rate of approximately 25 cubic feet per minute. At this rate, the time necessary to completely evacuate air from an empty 30-inch levee pipeline crossing is approximately 60 minutes.

To test this operation, on August 4, 2010, a portable vacuum pump was connected to the pipelines. The maximum vacuum able to be achieved by the equipment used was 15 inches of Hg. This produced a significant increase in flow through the pipelines. This quantity of flow required the operator to discontinue the test so that downstream facilities were not inundated. To be fully effective, the equipment will be required to produce a vacuum of approximately 19.5 inches of Hg, depending upon the water level in the distribution box. The equipment specified for this system is rated to produce a vacuum of 25 inches of Hg. The use of the vacuum pump to maximize siphon performance may produce more water than desired by the operator. The operator may need to shut down a pump, adjust the flow using the VFD system, or adjust the pressure target of the vacuum pump system, accordingly.

Design of Variable Frequency Drive System

The VFD system is an electrical device which can modulate the speed of the motor by changing the frequency of the alternating current delivered to the motor. The motor speed, and its corresponding output, is directly linear with the frequency. The VFD system is connected to Pump No. 1 and can operate that pump between 50 and 100 percent of its rated speed (890 rpm). The VFD can be used on a different pump with the same nameplate rating as Pump No. 1, but this would require new conduit and cable from the VFD to the pump motor. To transform the

VFD installation so that it can toggle between two pumps requires additional equipment not included in the design at this time.

Since the existing 75 hp motor for Pump No. 1 was not inverter duty-rated, it was not compatible with the additional heat stress that can be imparted by a VFD unit. Over time, such a stress would reduce the life of the motor. Therefore, a new motor suitable for use with a VFD was also included. The new motor matches the existing motor size of 75 hp. The VFD has been purposely oversized as a means to achieve lower running temperatures on account of its exterior operating environment.

The VFD can operate in two control modes: (1) speed control, and (2) level control. In speed control mode, the operator sets the motor speed as a percentage of the base speed, between a range of 50 and 100 percent. Under this control mode, the motor will run at the set speed without variation. Level control mode allows the operator to input a target elevation for the water surface in the distribution box and the motor will automatically modulate the speed of the motor to achieve and maintain this level. The VFD is equipped with a lock-out system that will prevent the VFD from operating more than 50 percent below the pump base speed, since exceeding 50 percent of the base speed is not recommended.

TABLES

TABLE 1

LEVEE DISTRICT NO. 1 – LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND

DATA ON EXISTING STAR BEND PUMP AND MOTOR UNITS

	VVF Pump	Pump No. 1	Pump No. 2	Pump No. 3	Pump No. 4*
Pump Manufacturer	Byron Jackson	Byron Jackson	Byron Jackson	Byron Jackson	Byron Jackson
Pump Model	18-inch PHRL	30-inch PHRL	35-inch PHRL	30-inch PHRL	17-inch HQH
Capacity, GPM	3,100	8,500	11,250	8,500	3,000
Head	30-foot	30-foot	30-foot	30-foot	30-foot
Motor HP	30	75	100	75	60
Motor RPM	N/A	890	710	890	1175

*Note: Pump No. 4 information is based upon Kit Burton's assumptions included in curves developed for his July 8, 2010 memorandum.

TABLE 2
LEVEE DISTRICT NO. 1 OF SUTTER COUNTY - LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND
DETERMINATION OF PRE AND POST PROJECT TOTAL DYNAMIC HEAD

Pipe friction losses are based upon the Darcy-Weisbach equation $H_f = f * L/D * H_v$

Assumed Static Lift based upon existing information = 25.0 feet

											Minor Losses						Total	
Q, gpm	**V**	**Hv**	**Hf**	**V**	**Hv**	**Hf**	**V**	**Hv**	**Hf**	**Total Hf**	**Elbows**	**Tees**	**Valves**	**Wye**	**Exit**	**Total**	**HT**	**TDH**
	Pre-Project System																	
	24" WSP, f =.026			**26" WSP, f =.026**				**Pipe 1, 24" WSP**				**Pipe 2, 26" WSP**			**Pipe 3, 24" WSP**			
	V	**Hv**	**Hf**	**V**	**Hv**	**Hf**		**Hf**	**Elbows**	**Exit**	**TDH**	**Elbows**	**Exit**	**TDH**	**Elbows**	**Valves**	**Exit**	**TDH**
4000	2.84	0.125	0.349	2.41	0.090	0.252		0.349	0.375	0.312	26.037	0.270	0.09	25.61	0.37	0.31	0.35	26.4
5000	3.55	0.195	0.546	3.01	0.141	0.394		0.546	0.586	0.488	26.620	0.423	0.14	25.96	0.59	0.49	0.55	27.2
6000	4.26	0.281	0.786	3.61	0.203	0.567		0.786	0.844	0.703	27.333	0.609	0.20	26.38	0.84	0.70	0.79	28.1
7000	4.97	0.383	1.070	4.22	0.276	0.772		1.070	1.148	0.957	28.175	0.828	0.28	26.88	1.15	0.96	1.07	29.2
8000	5.67	0.500	1.397	4.82	0.361	1.008		1.397	1.500	1.250	29.147	1.082	0.36	27.45	1.50	1.25	1.40	30.5
9000	6.38	0.633	1.769	5.42	0.456	1.276		1.769	1.898	1.582	30.249	1.369	0.46	28.10	1.90	1.58	1.77	32.0
10000	7.09	0.781	2.183	6.02	0.563	1.575		2.183	2.344	1.953	31.480	1.690	0.56	28.83	2.34	1.95	2.18	33.7
11000	7.80	0.945	2.642	6.63	0.682	1.905		2.642	2.836	2.363	32.841	2.045	0.68	29.63	2.84	2.36	2.64	35.5

	Post-Project System																	
	48" CCP, f= .012			**30" WSP, f= .014**			**24" WSP, f= .026**											
5000	0.89	0.012	0.059	1.13	0.020	0.031	1.77	0.049	0.025	0.115	0.060	0.059	0.136	0.004	0.020	0.278	0.39	25.4
7500	1.33	0.027	0.132	1.70	0.045	0.070	2.66	0.110	0.057	0.260	0.135	0.132	0.306	0.009	0.045	0.626	0.89	25.9
10000	1.77	0.049	0.235	2.27	0.080	0.125	3.55	0.195	0.102	0.462	0.240	0.234	0.543	0.016	0.080	1.113	1.57	26.6
15000	2.66	0.110	0.529	3.40	0.180	0.281	5.32	0.439	0.229	1.039	0.540	0.527	1.222	0.035	0.180	2.505	3.54	28.5
20000	3.55	0.195	0.940	4.54	0.320	0.500	7.09	0.781	0.406	1.847	0.960	0.937	2.173	0.062	0.320	4.453	6.30	31.3
25000	4.43	0.305	1.469	5.67	0.500	0.781	8.87	1.221	0.635	2.885	1.500	1.465	3.396	0.097	0.500	6.958	9.84	34.8
30000	5.32	0.439	2.116	6.81	0.720	1.125	10.64	1.758	0.914	4.155	2.160	2.109	4.890	0.140	0.720	10.019	14.17	39.2

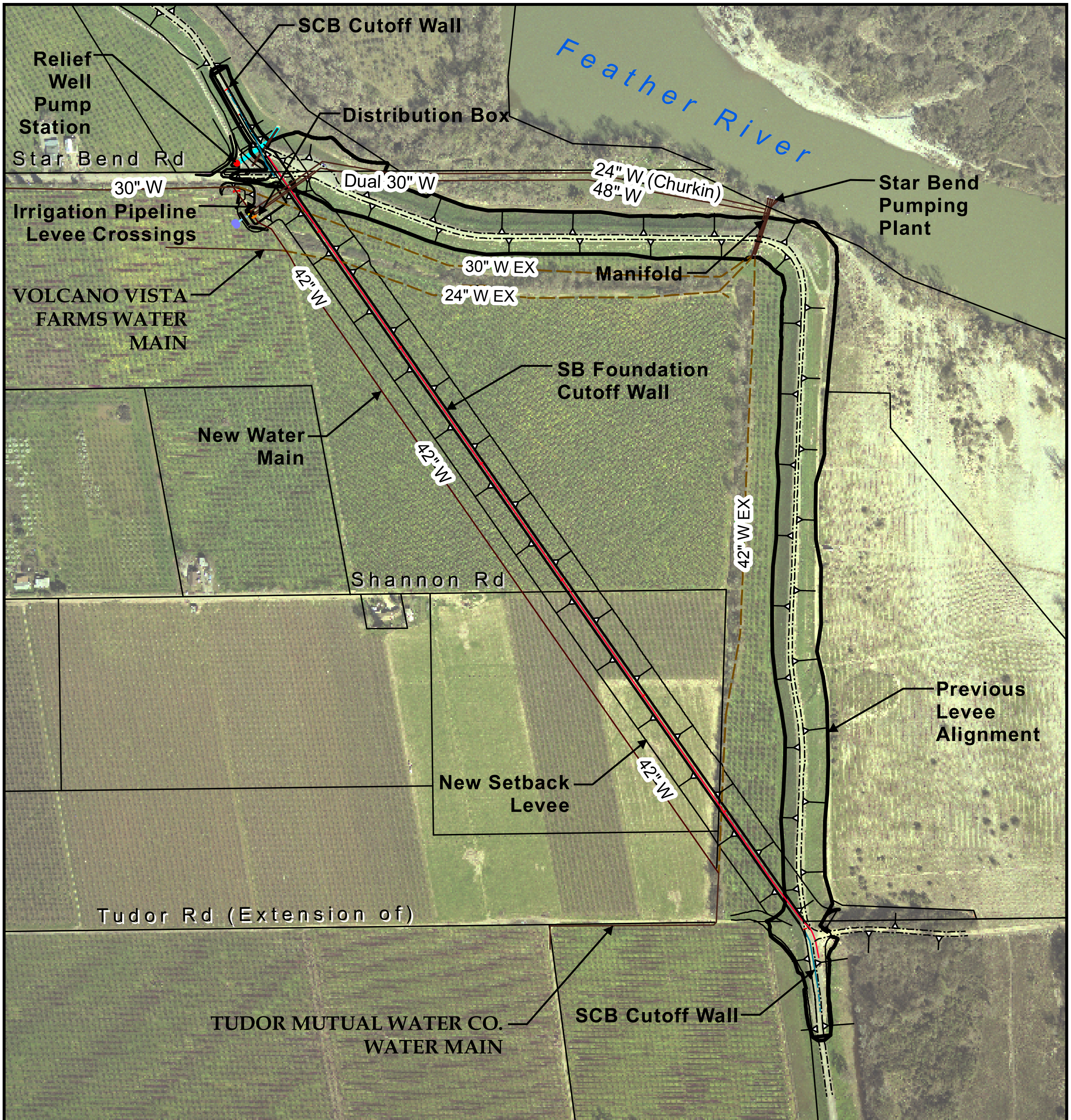
		Relative roughness		
Roughness		**48"**	**30"**	**24"**
New CCP	0.0005	0.0001	0.0002	
Old WSP	0.0055			0.0028
f		**0.012**	**0.014**	**0.026**

Minor Losses

	K
Elbow	0.6
Gate Valve	0.19
Check	2.5
Tee	0.6
Exit	1
Wye	0.5

Pipe	**Feet**	
24" WSP	215	Pre
26" WSP	215	
48" CCP	1605	
30" WSP	279	Post
24' WSP	40	

FIGURES



W EX = Existing Pipe Line Abandoned or Removed
W = New Water Line

FIGURE 1
STAR BEND SETBACK LEVEE AND TUDOR MUTUAL WATER COMPANY IRRIGATION FACILITIES

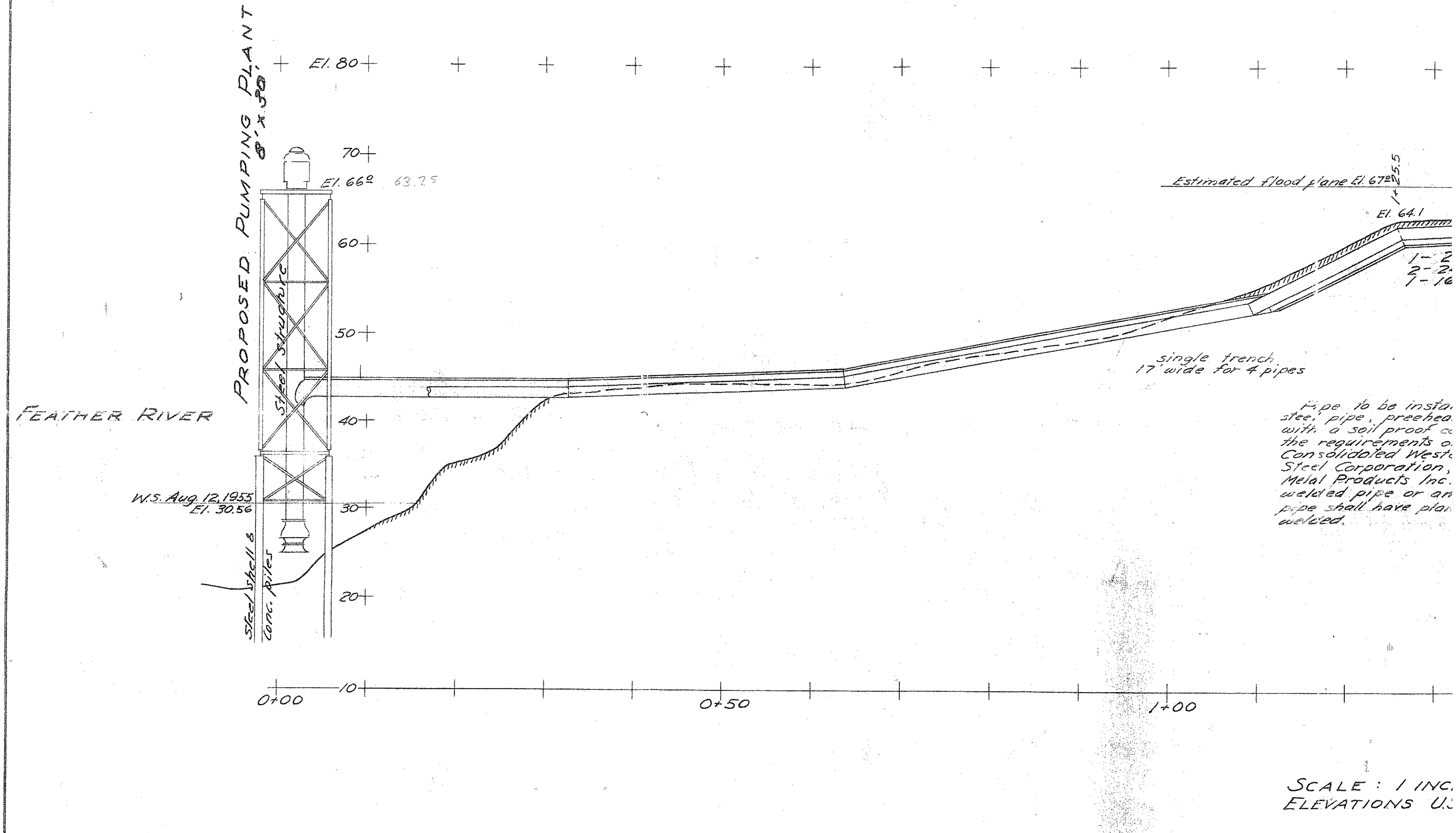
LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND
SUTTER COUNTY, CALIFORNIA
SEPTEMBER 2010

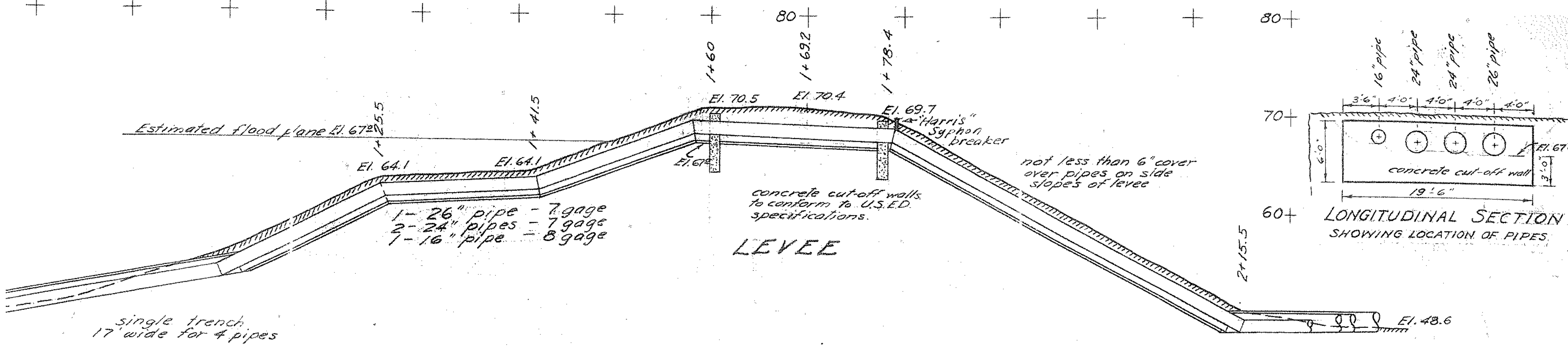
NORTH

0 250 500
FEET

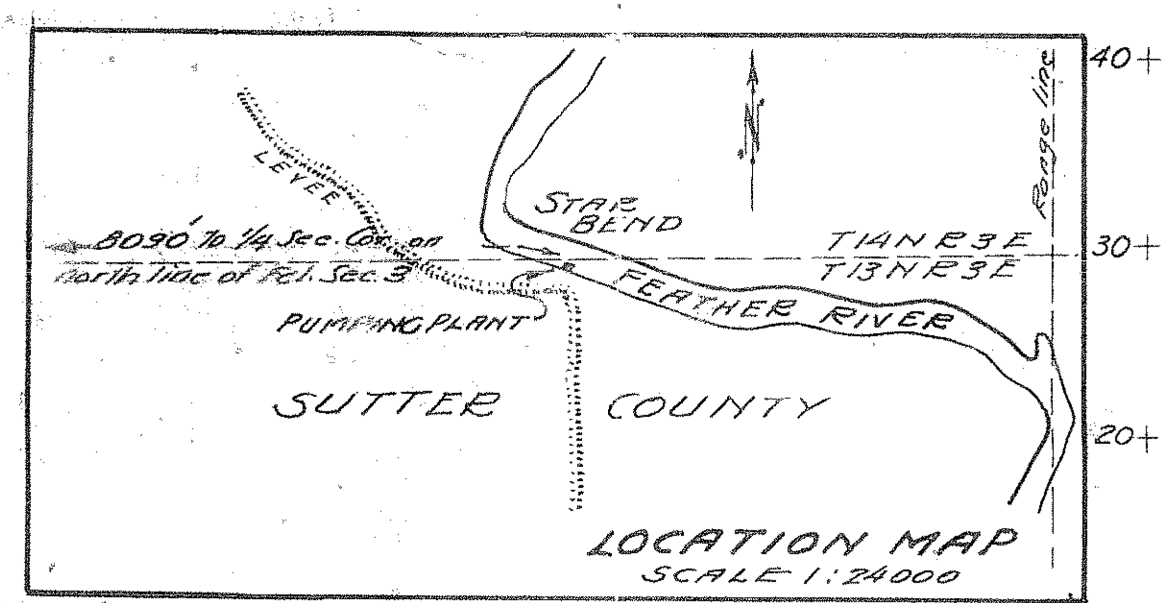
WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C Street, Bldg. 100-B Tel: 916.341.7760
Sacramento, CA 95816 Fax: 916.341.7767

FIGURE 2
1 OF 2





Pipe to be installed shall be smooth steel pipe, preeheated and asphalt dipped, with a soil proof covering conforming to the requirements of the specifications of Consolidated Western Steel Division - U.S. Steel Corporation, Armco Drainage & Metal Products Inc. specifications for spiral welded pipe or an approved equal. The pipe shall have plain ends and shall be field welded.



SCALE : 1 INCH = 10 FEET
ELEVATIONS U.S.E.D. DATUM

EXHIBIT B

CROSS SECTION OF THE LEVEE OF LEVEE DISTRICT No. 1 OF SUTTER COUNTY, CALIF. SHOWING PROPOSED PIPES TO BE INSTALLED FOR TUDOR MUTUAL WATER COMPANY

EDWARD von GELDERN
CIVIL ENGINEER

AUGUST 15, 1955

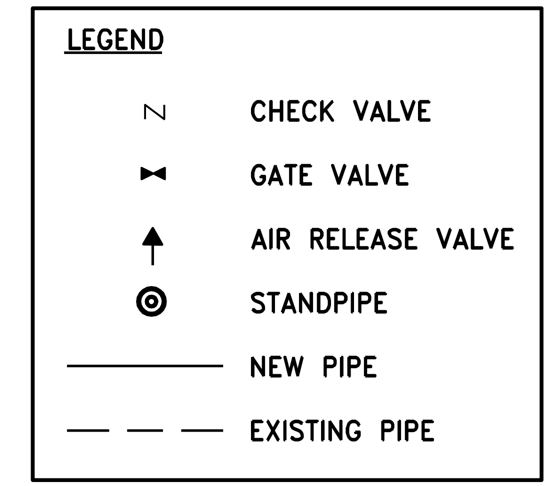
FIGURE 3

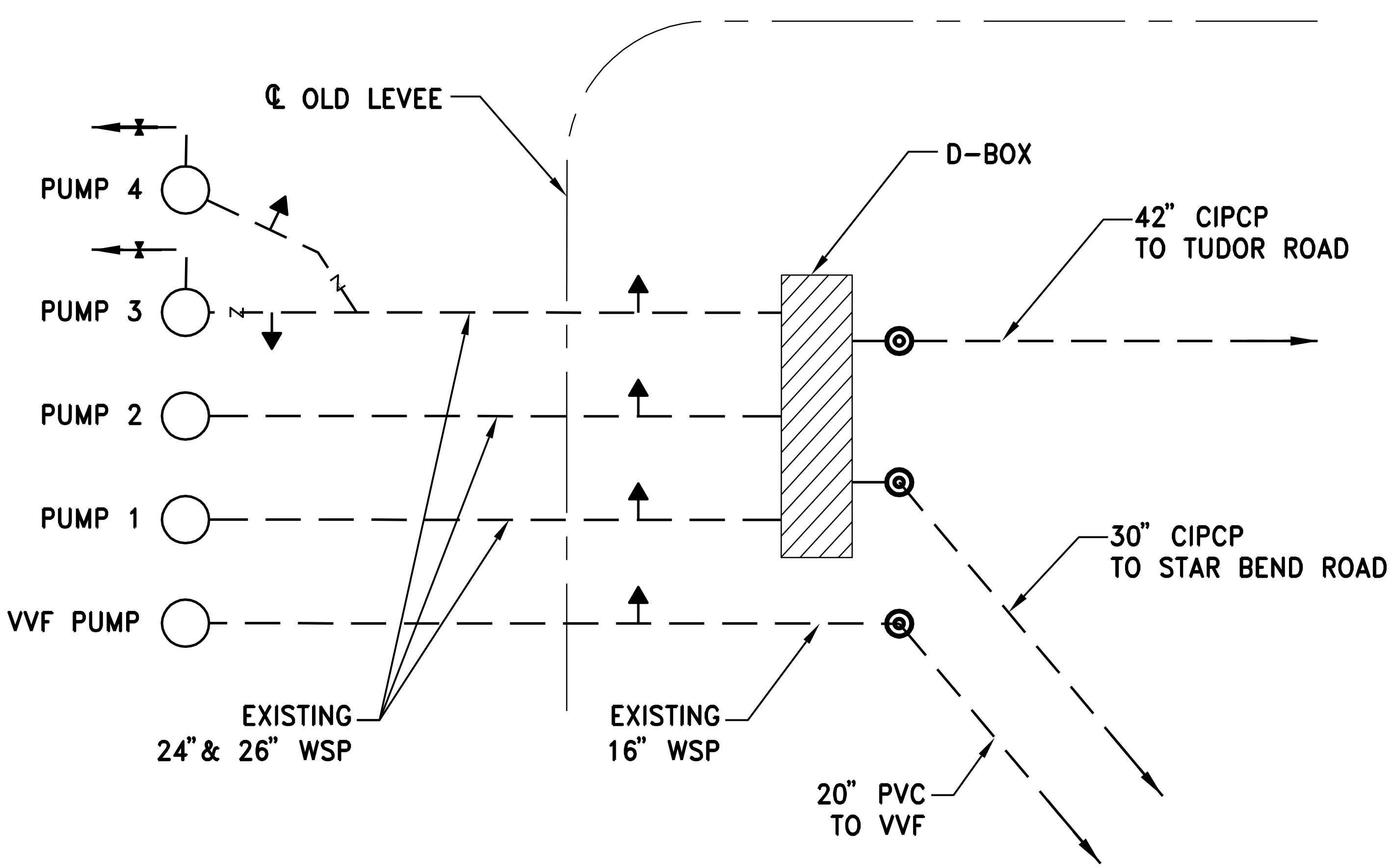
LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND

YUBA FEATHER FLOOD PROTECTION PROGRAM

SUTTER COUNTY CALIFORNIA

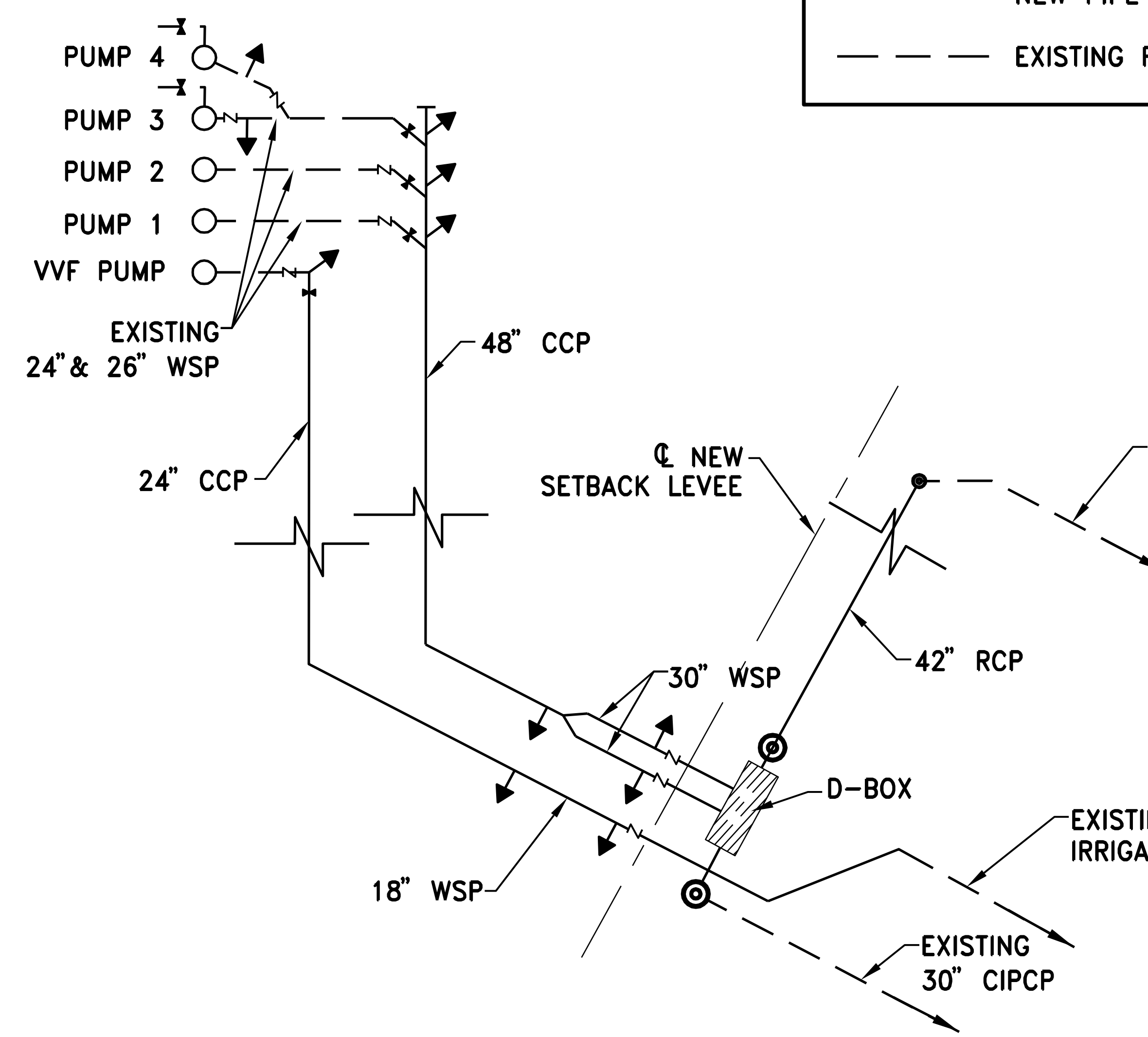
AUGUST, 2010





SCHEMATIC PLAN - PRE-PROJECT SYSTEM

N.T.S.

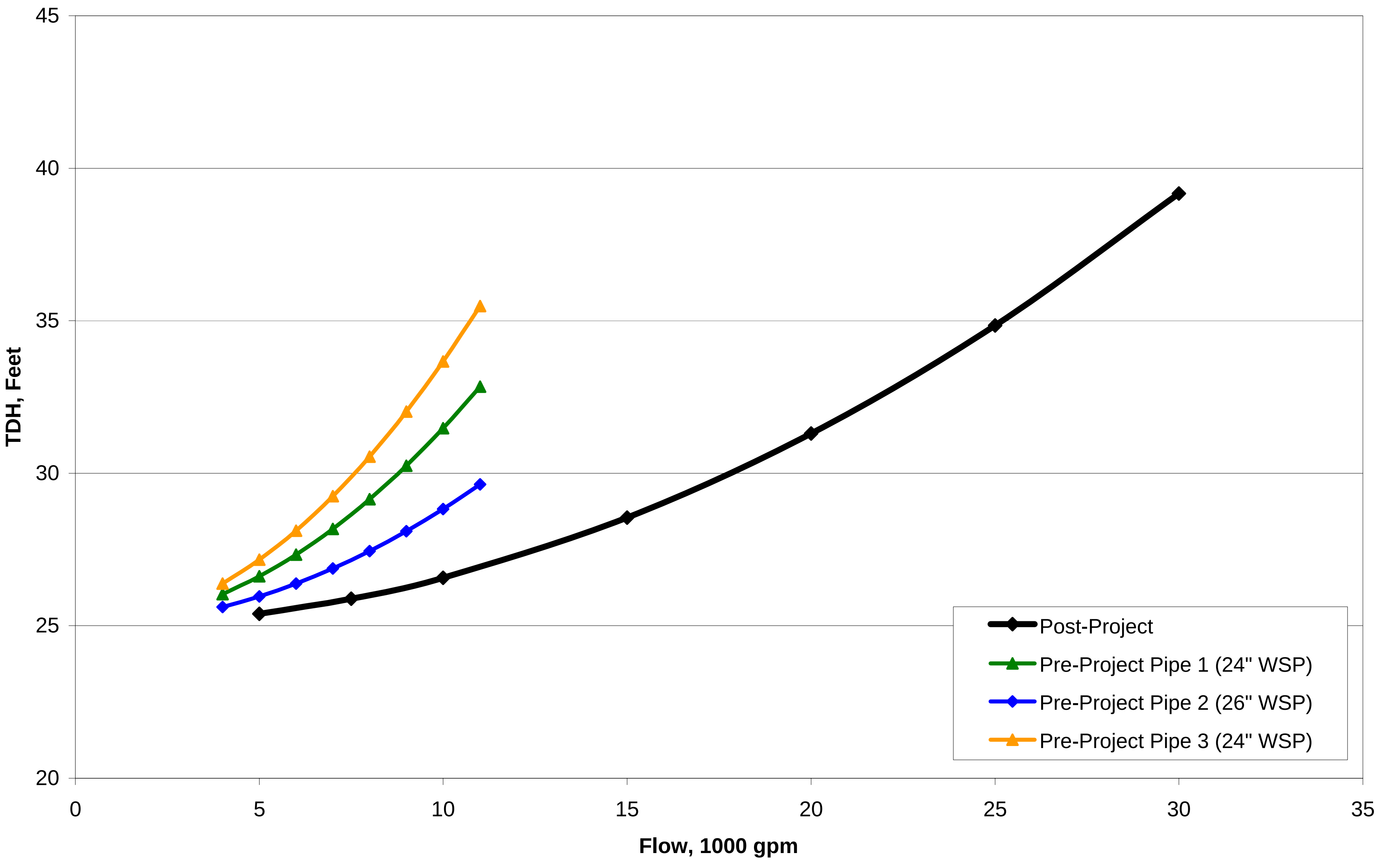


SCHEMATIC PLAN - MODIFIED SYSTEM

N.T.S.

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C St, Bldg. 100-B Tel 916.341.7760
Sacramento, CA 95816 Fax 916.341.7767

FIGURE 4
DISCHARGE SYSTEM CURVES
25-ft Static Lift, Siphon Condition

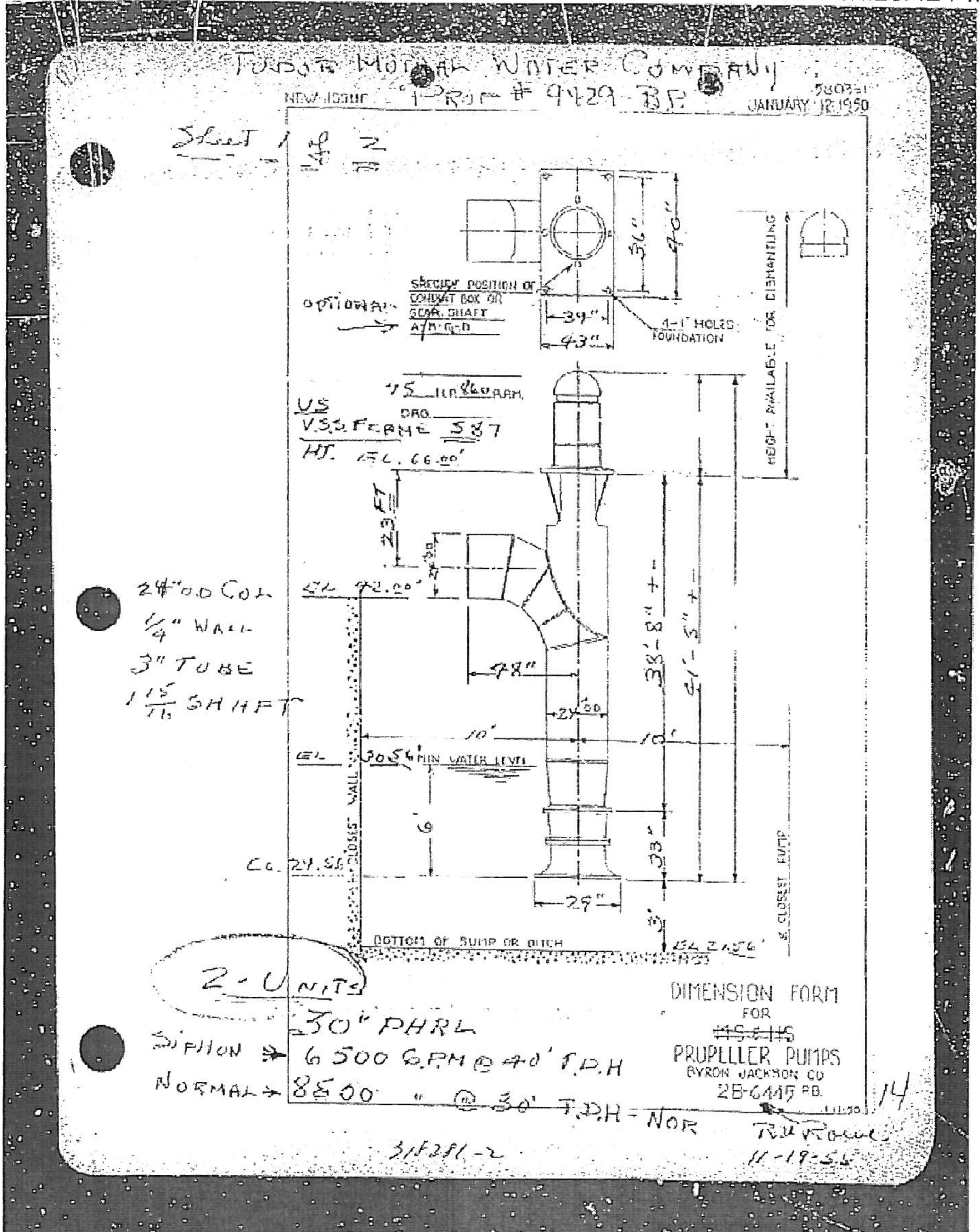


APPENDICES

APPENDIX A

Date: 1/26/2005

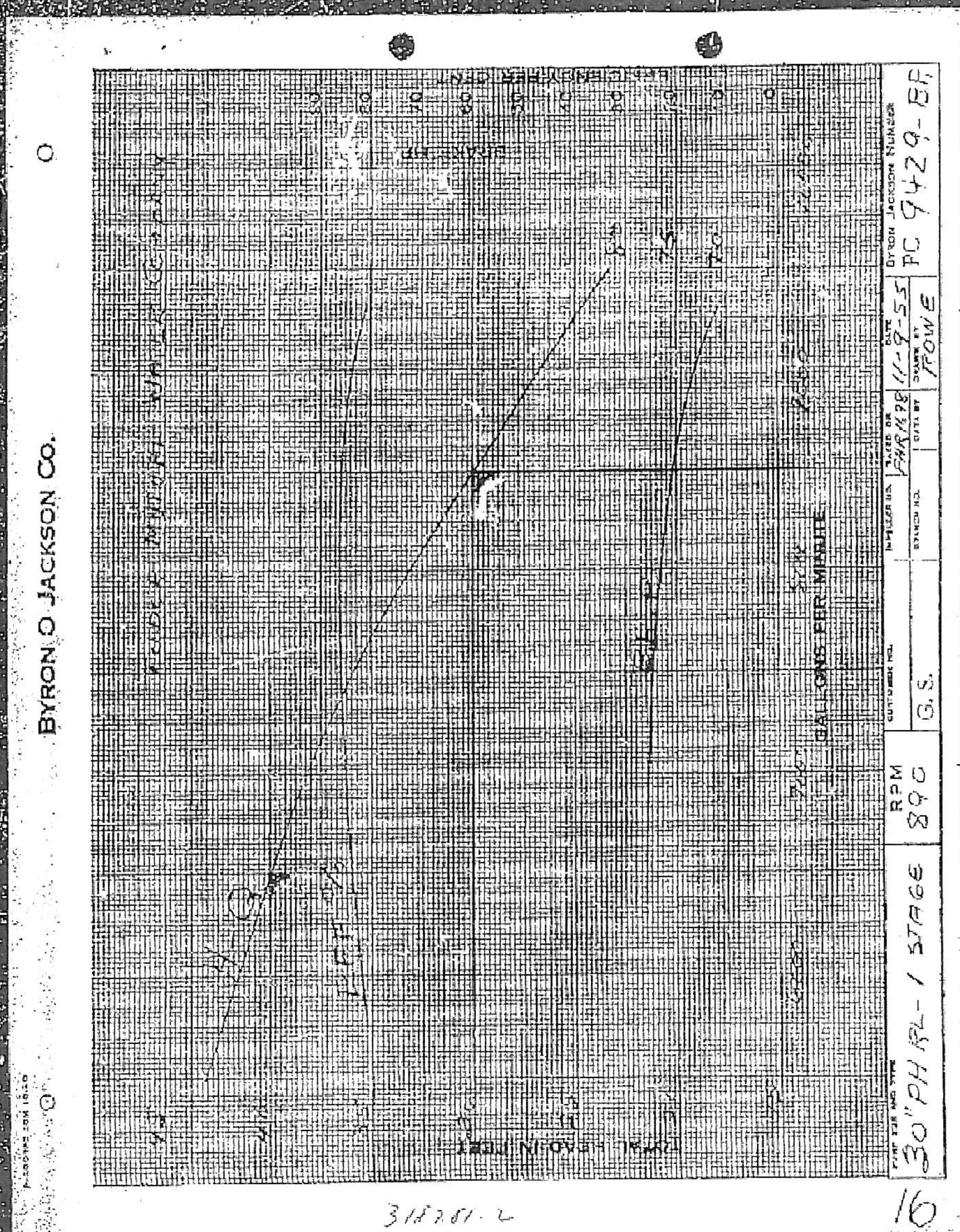
Time : 02:23:42 PM



Title: C:\DOCUME~1\dhartman\LOCALS~1\Temp\c.lotus.notes.data\318281.tif

Date: 1/26/2005

Time : 02:23:30 PM

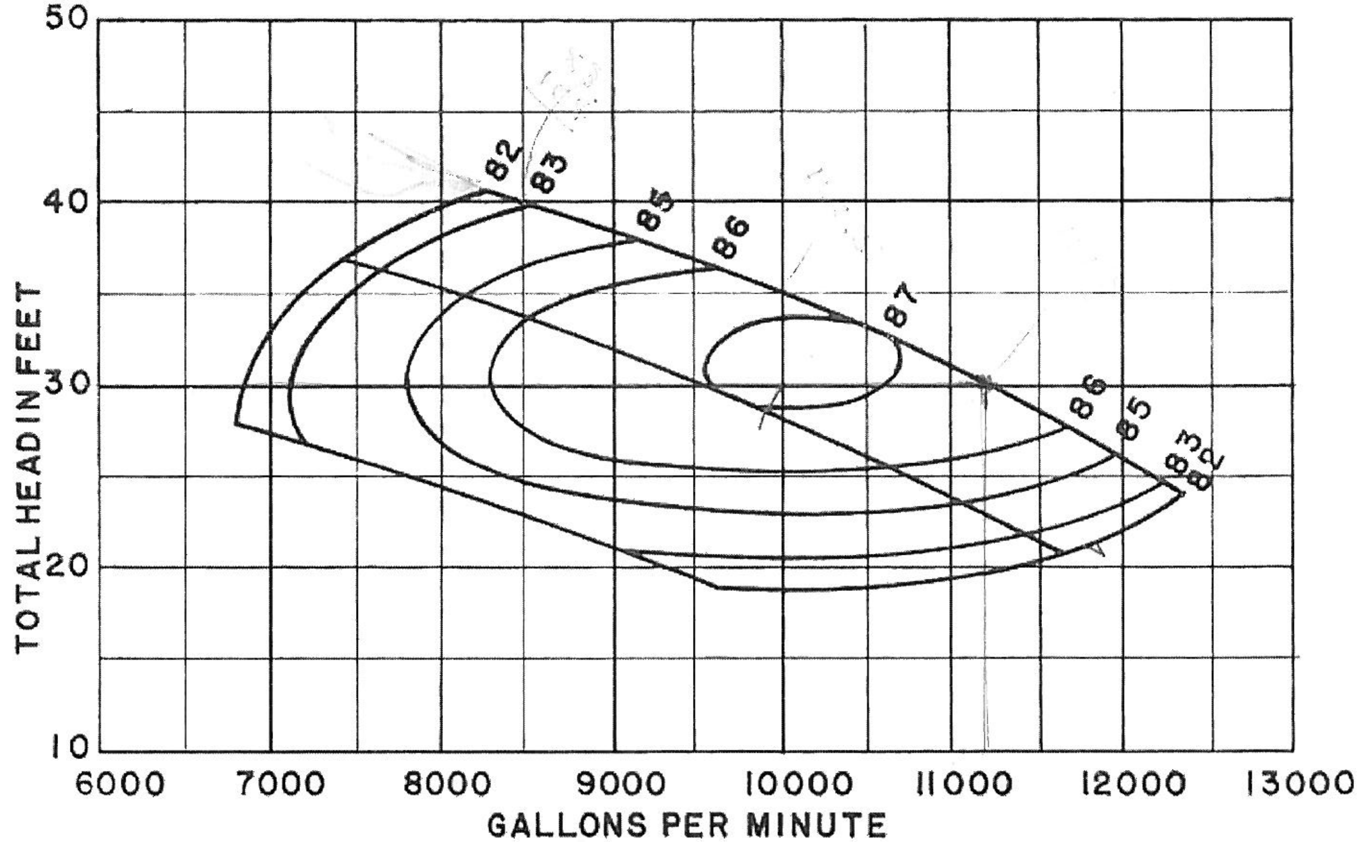


318281-2

16

Title: C:\DOCUME~1\dhartman\LOCALS~1\Temp\c.lotus.notes.data\318281.tif

35" PHRL 710



HEAD AT CLOSED VALVE = 1.8 X PEAK EFF.
BHP AT CLOSED VALVE = 1.3 X PEAK EFF.
"U" AT 710 RPM = 54.6 FT. PER SEC.

$$\frac{10650 \text{ GPM} \times 32.6 \text{ FT}}{3960 \times 0.87} = 101 \text{ BHP}$$

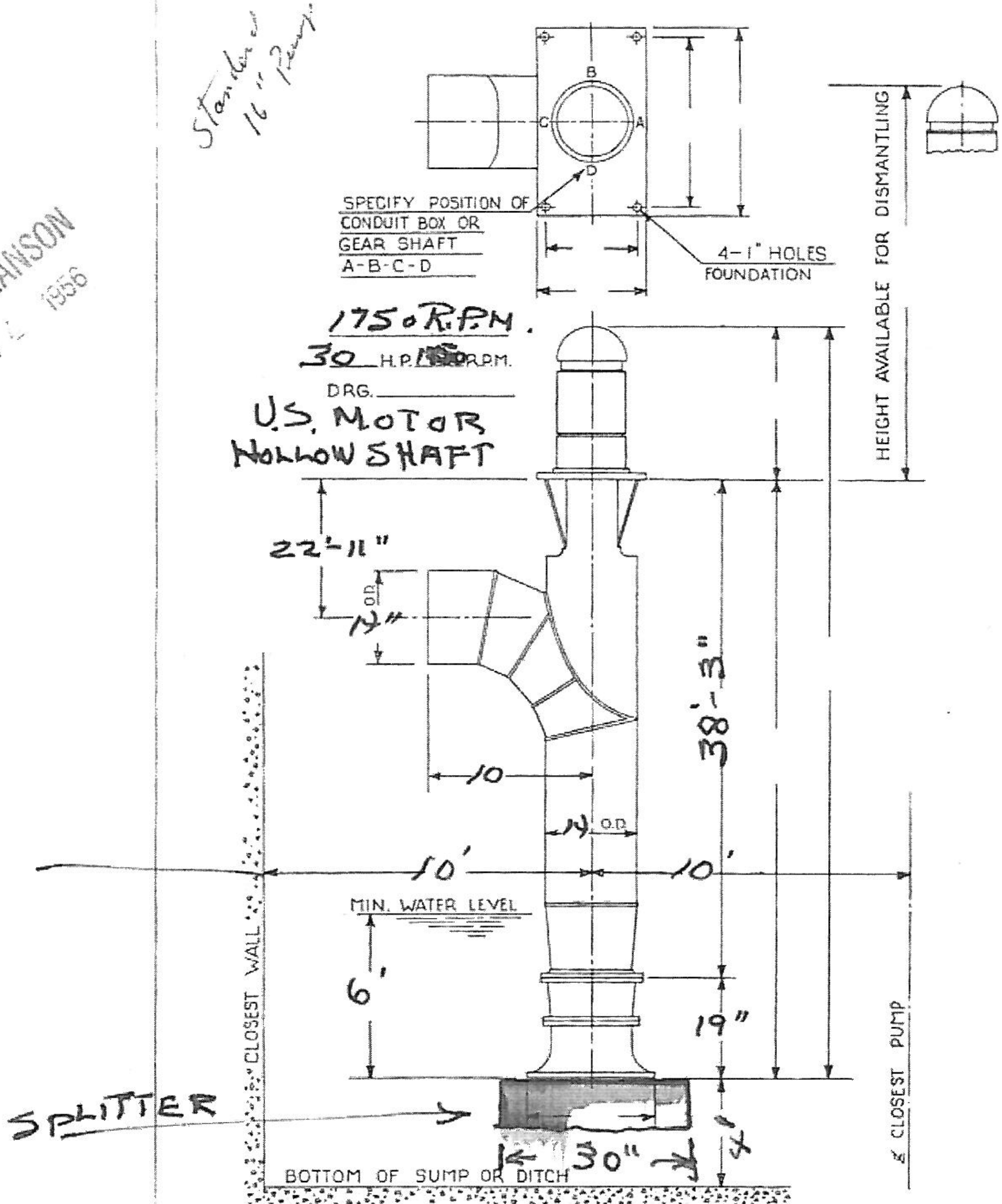
PUMP SIZE AND TYPE	RPM	EYE AREA = 212 SQ. IN.	DRAWN BY	DATE	BYRON JACKSON RATING
35" PHRL	710	1.58 x RA 2812-1	RWA	7-26-51	PHR 1702
			SUPERSEDES	DATE	

CHURKINS

Grover C. Shannon JOB

NEW ISSUE — Yuba City — 5803-1 — JANUARY 12, 1950

Standard 16" Pump.

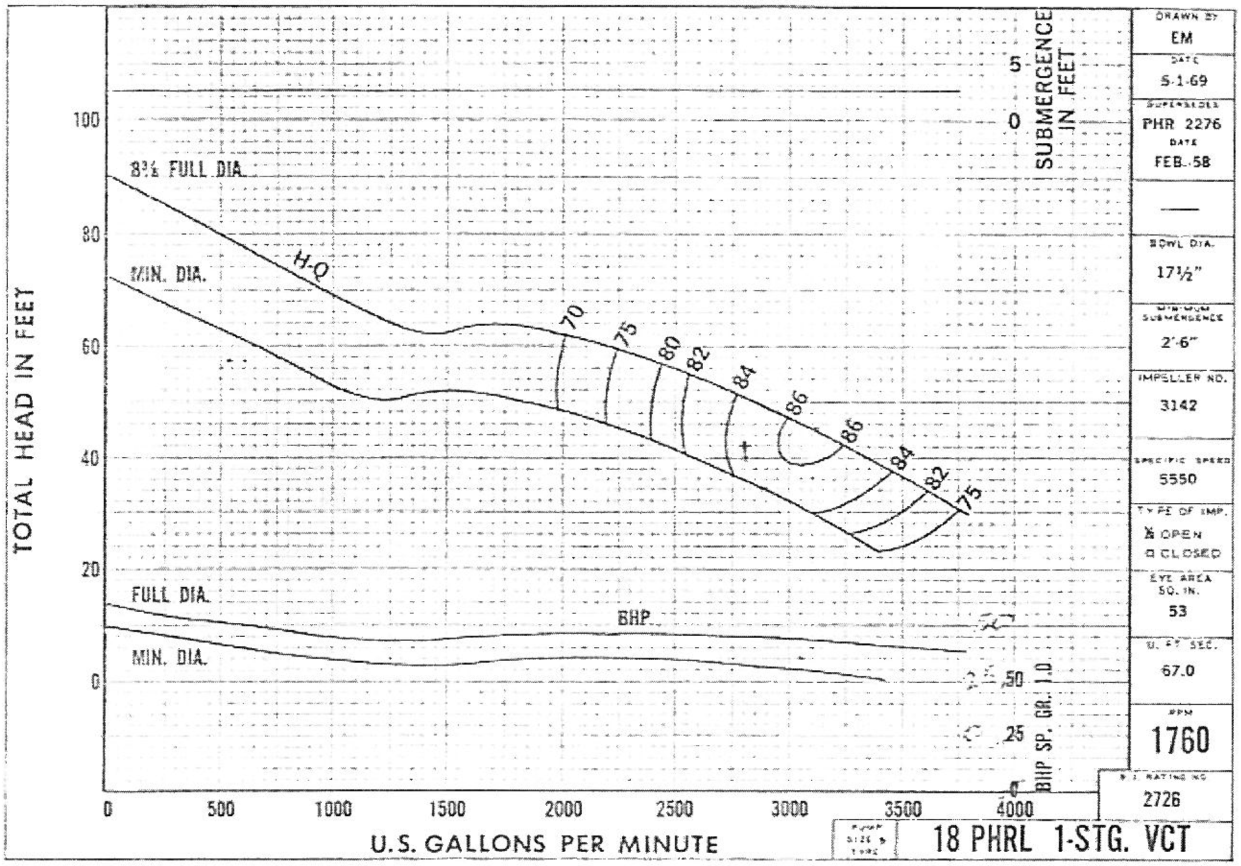


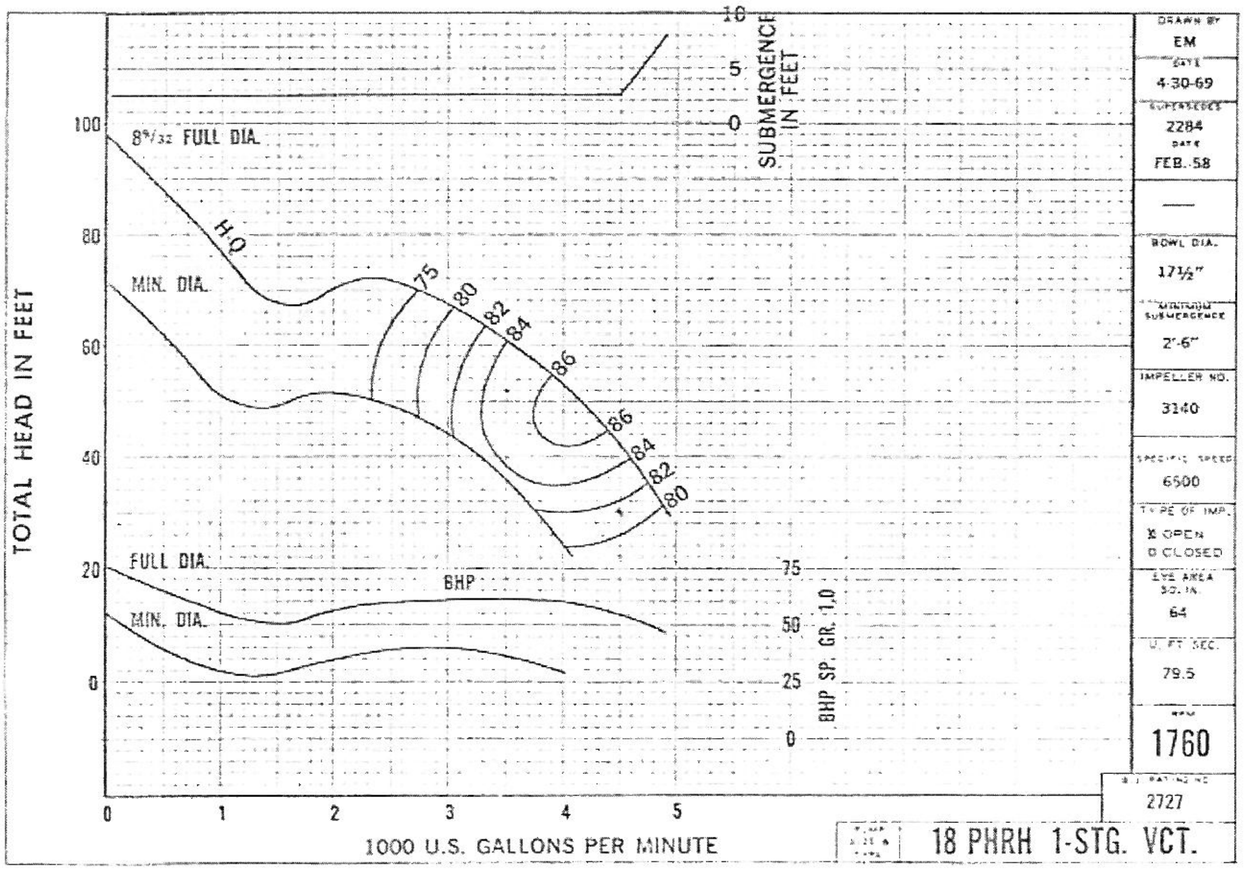
18" PHRL
3100 G.P.M @ 30' T.D.H
approx 2500 " @ 40' T.D.H.
PRIME SIPHON

DIMENSION FORM
FOR
MS & HS
PROPELLER PUMPS
BYRON JACKSON CO
2B 6445 B

1-1-50

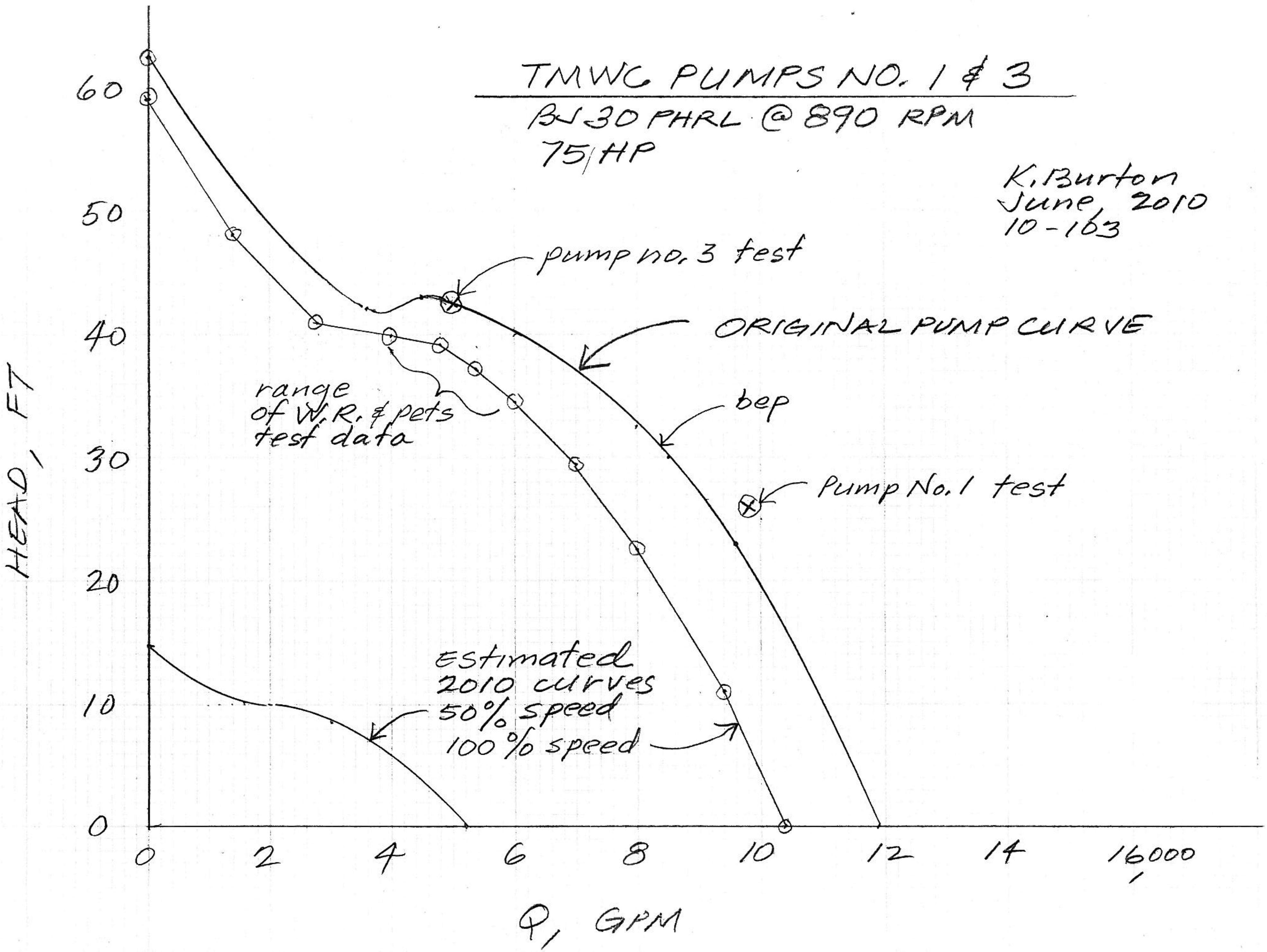
Byron Jackson Pump Division
BORG-WARNER CORPORATION

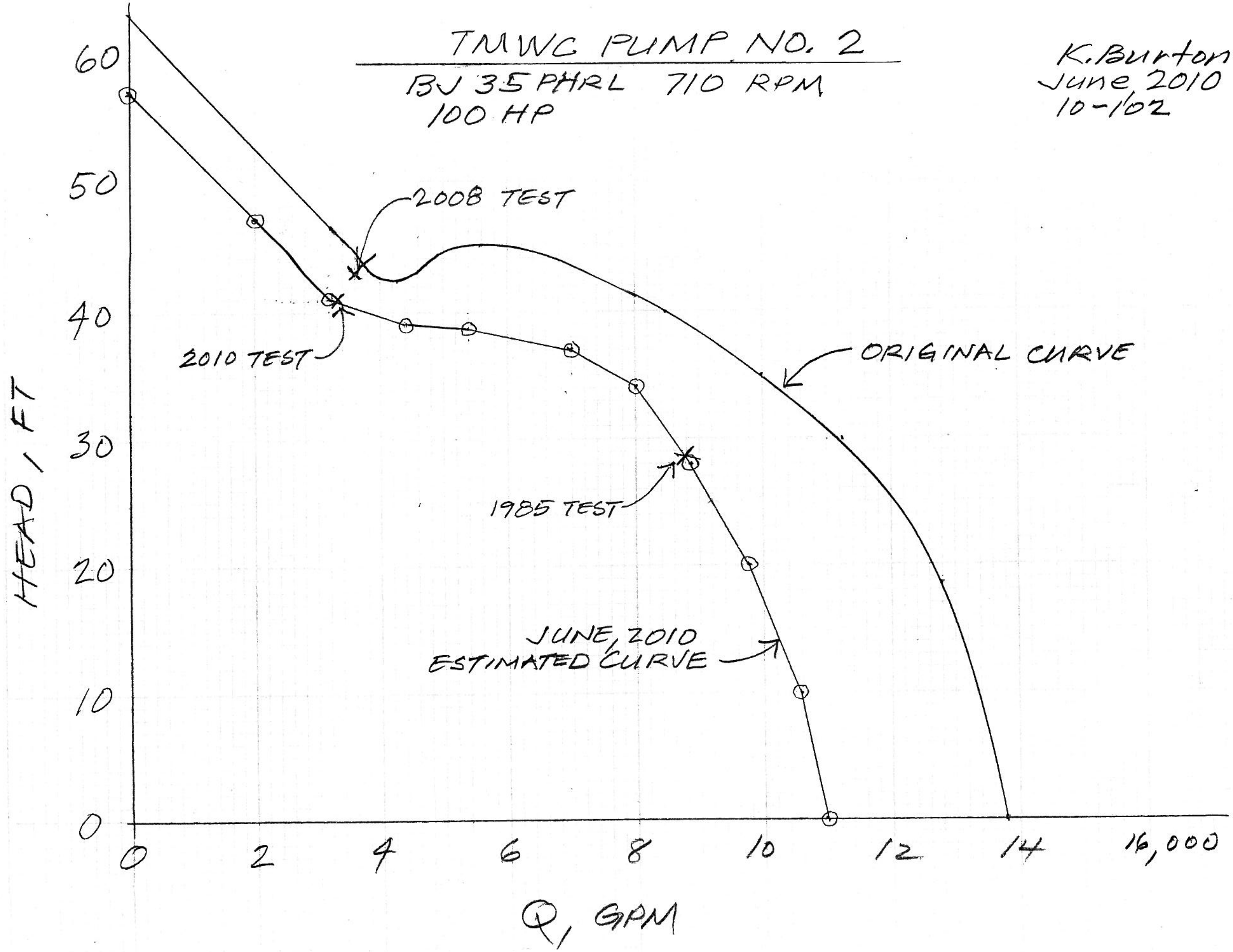


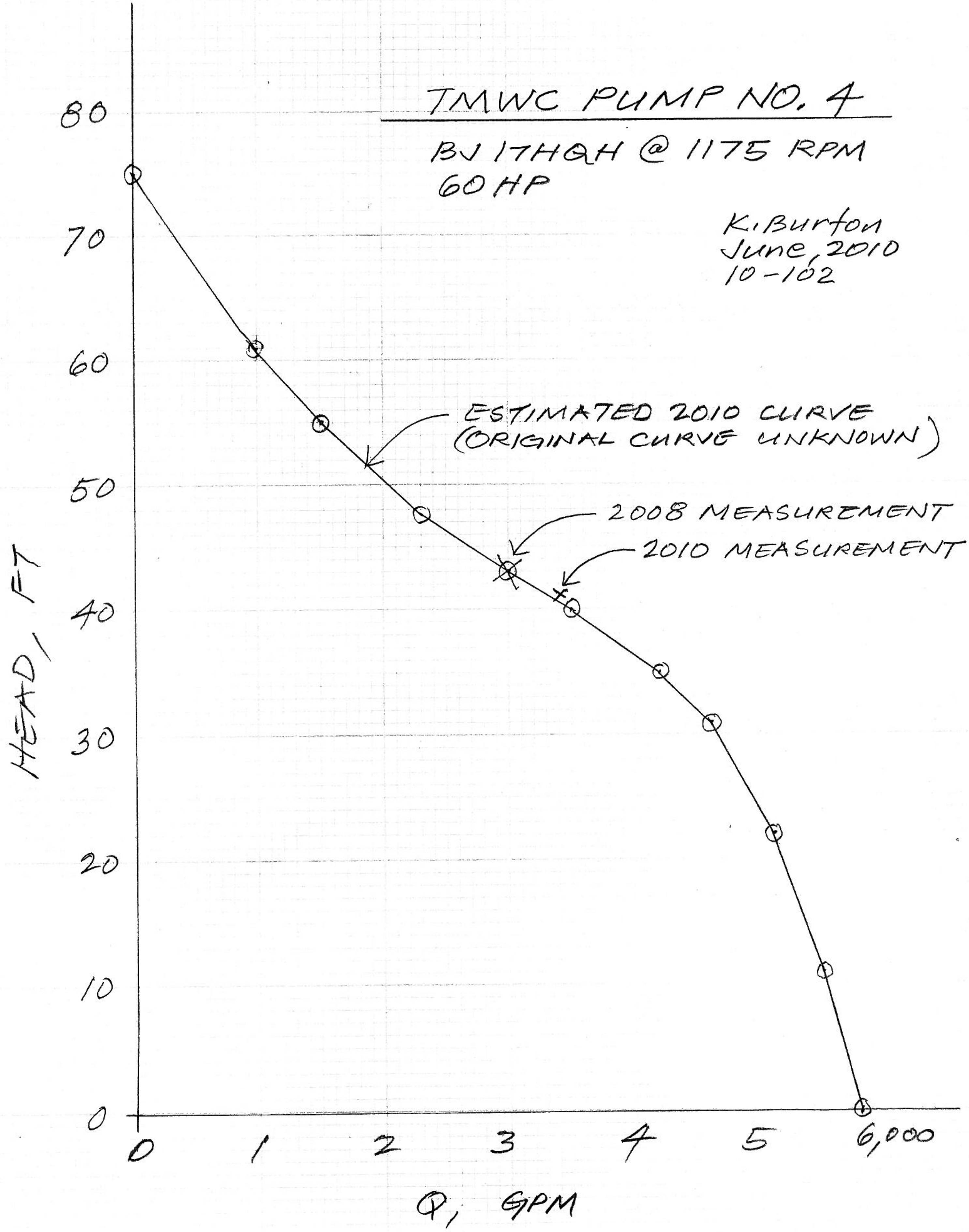


PHR 913

APPENDIX B


TMWC PUMPS NO. 1 & 3
BJ 30 PHRL @ 890 RPM
75 HP
K. Burton
June, 2010
10-163
pump no. 3 test
ORIGINAL PUMP CURVE
bep
Pump No. 1 test
range of W.R. & pets test data
Estimated 2010 curves
50% speed
100% speed
HEAD, FT
Q, GPM
0
10
20
30
40
50
60
2
4
6
8
10
12
14
16,000


TMWC PUMP NO. 2
BJ 35 PHRL 710 RPM
100 HP
K. Burton
June, 2010
10-102
2008 TEST
2010 TEST
ORIGINAL CURVE
1985 TEST
JUNE, 2010
ESTIMATED CURVE
HEAD, FT
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16,000
Q, GPM


TMWC PUMP NO. 4
BJ 17HQH @ 1175 RPM
60 HP
K. Burton
June, 2010
10-102
ESTIMATED 2010 CURVE
(ORIGINAL CURVE UNKNOWN)
2008 MEASUREMENT
2010 MEASUREMENT
HEAD, FT
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6,000
Q, GPM