ARCADIS Design & Consultancy for natural and built assets

Mr. Clece Aurelus
Engineering Support Services Manager
City of Hollywood Public Utilities
1621 North 14th Avenue
Hollywood, FL 33022-9045

Sent via email: caurelus@hollywoodfl.org

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8201 Peters Road
Suite 2400
Plantation
Florida 33324
Tel 954 761 3460
Fax 954 761 7939
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WATER

Subject:
Proposal – High Service Pump Station Physical Hydraulic Model Study

Date:
July 28, 2016

Contact:
Robert Daoust

Phone:
954.414.9016

Email:
robert.daoust@arcadis.com

Our ref:
00361334.2016

Florida License Numbers

Engineering

7917

Geology

GB564

Surveying

LB7062

Dear Mr. Aurelus:

In 2015, the City of Hollywood (City) tasked Arcadis U.S., Inc. (Arcadis) with the preparation of a technical memorandum to identify the design criteria and staged sequence construction plan for needed improvements and upgrades to the City's high service pump station (HSPS). A draft of the technical memorandum was submitted to the City on April 4, 2016.

As reported in our technical memorandum, the piping configuration in the sump areas of the clear wells does not conform to Hydraulic Institute (Institute) standards. Conformance to these standard is critical to ensure proper pump performance and trouble free operation. Where piping configurations are not standard, such as the case here, the Institute strongly recommends physical hydraulic modeling to document that the non-standard piping approach does not lead to pump performance problems due to the formation of vortexes or swirling currents entering the pumps. Consequently, Arcadis believes it is in the City's interest to conduct a physical hydraulic model study of the pump suction piping inside the clear wells to ensure that when new pumps are installed in the HSPS they will operate without problems and produce required flow rates.

Physical hydraulic modelling requires specialized facilities that Arcadis cannot provide. However, we have worked with numerous partners on similar projects for other clients and based upon this experience, we reached out to Clemson Engineering Hydraulics, Inc. (CEH), one of the most distinguished facilities in the country providing these services. CEH is ready and able to assist the City and has prepared a detailed scope of work and fee to conduct the recommended physical hydraulic modeling, which has been attached to this proposal for your review.

In accordance with the terms and conditions of the Professional Engineering Services Agreement (Agreement) between the City and Malcolm Pirnie, Inc., as assigned to Arcadis, we are proposing to provide the described scope of services (Letter Proposal, attached) to the City, in partnership with CEH, for a lump sum fee of $46,200. This fee includes payment in the amount of $42,000 to CEH, plus the allowable 10% markup by Arcadis ($4,200) to cover our associated administrative and project management costs.

Sincerely,
Arcadis U.S., Inc.

Robert J. Daoust
Associate Vice President

Copies:
Plantation Files
B. Duane (Arcadis)
Clemson Engineering Hydraulics, inc.

Attachments:
Letter Proposal – June 30, 2016 – Clemson Engineering Hydraulics, Inc.

CLEMSON ENGINEERING HYDRAULICS, INC.
1046 Watkins Road • Anderson, SC 29625
P 864.231.9585 F 864.231.9588 W www.ceh-lab.com

June 30, 2016

Brian F. Duane, PE
Arcadis U.S., Inc.
2410 Paces Ferry Road, Suite 400
Atlanta, GA 30339 | USA

Ref: Hollywood WTP Pump Station

Dear Mr. Duane,

Thank you for the opportunity to provide you with a quotation to conduct a physical hydraulic model study of the Trussville WWTP Influent Pump Station. We have conducted numerous wastewater suction elbow type intake pump modeling projects and our lab is fully equipped to comply with the Hydraulic Institute testing and reporting requirements.

INTRODUCTION

Arcadis has requested that Clemson Engineering Hydraulics, Inc. (CEH) assist them by preparing a proposal to conduct a physical hydraulic model study of the existing Hollywood WTP pump station. The pump station currently houses ten (10) pumps ranging between 3,500 and 14,000 gpm in two side-by side wet-wells. The pumps utilize 30 and 36-inch 90-degree turn-down suction elbows before reducing down to the different pump suctions. Arcadis is proposing to replace all pumps with three (3) 8,000 gpm pumps and two (2) 10,000 gpm pumps in each side. Each sump is adjacent to a large clear well.

Each side of the intake is similar but not exactly symmetrical due to a sloping floor that slopes in the same direction in each wet well resulting in slightly different submergence on the pumps depending on the wet well. However, they are similar enough in spacing and orientation to allow for modeling of only one half of the station (5 pumps) and extrapolating the results to the adjacent side with confidence.

SIMILAR MODELING EXPERIENCE

CEH has conducted numerous studies of very similar intakes in the past. Photos 1 through 6 show several models CEH recently conducted with similar suction arrangements in both our indoor and outdoor model basins.

Photo 1 Similar Wet With Suction Elbows

Photo 2 Similar Wet Well with Multiple Pump Suctions


Photo 3 CEH Can Simulate Any Type of Suction Elbow
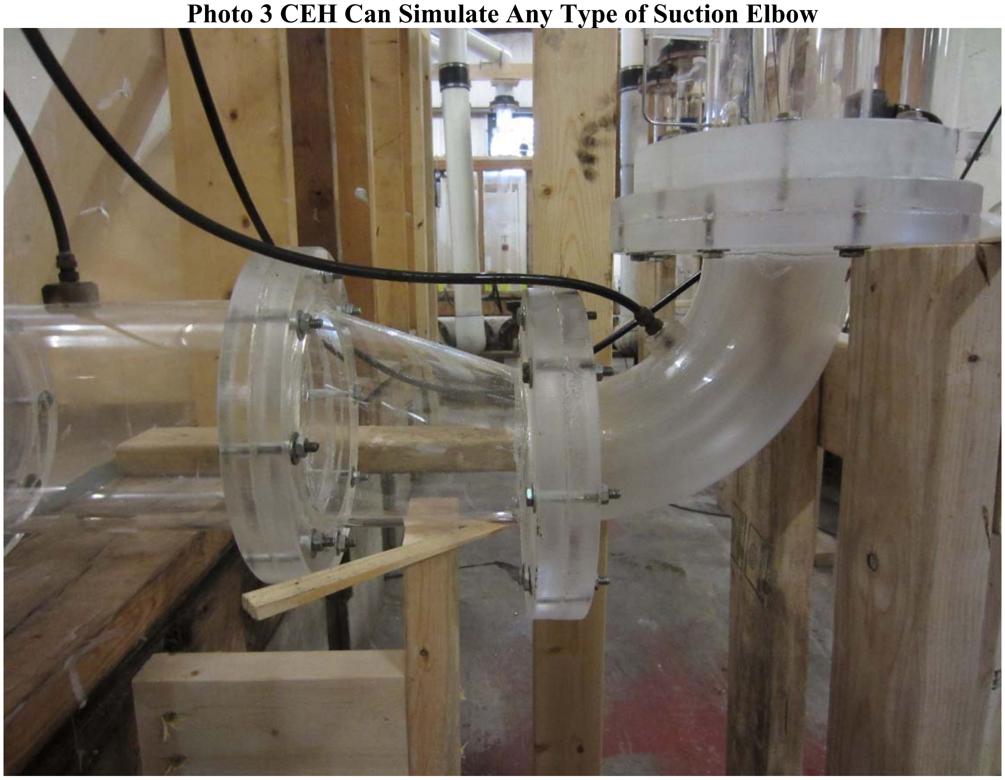
Photo 4 CEH Has In-House Fabrication Capability for Any Size / Shape Fitting

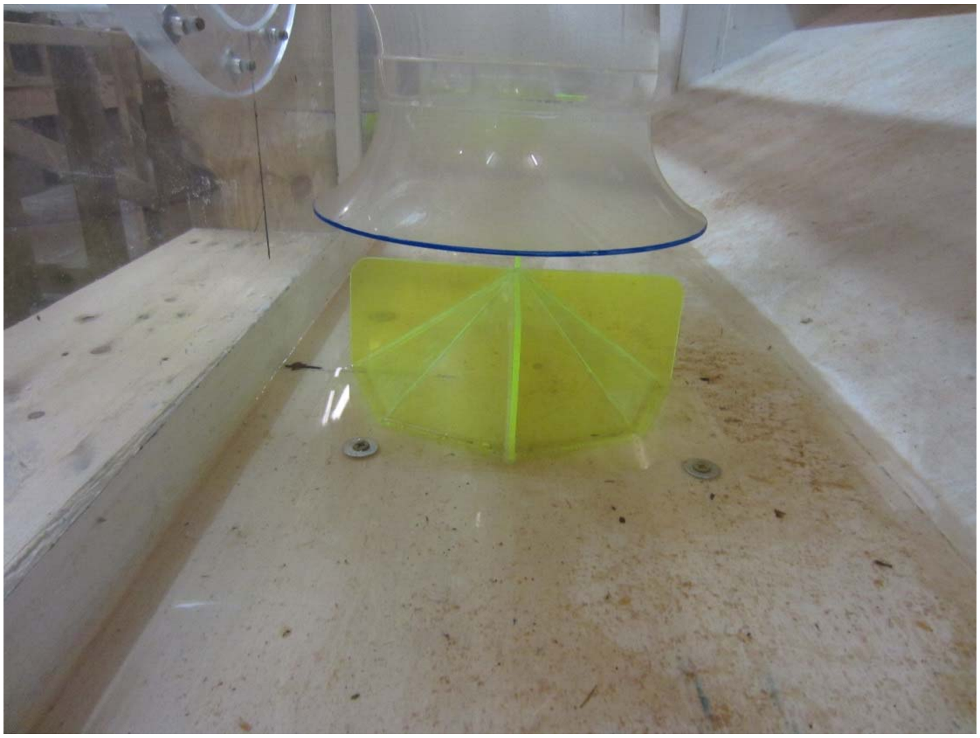

Photo 5 CEH Regularly Tests Floor Cones (these are shown on the as-built)

Photo 6 CEH Can Develop Specialized Remedial Measures Vanes / Straighteners as Needed

CEH has complete in-house acrylic fabrication capabilities to simulate any piping components. CEH maintains and operates, entirely in-house at our facilities, 3-D routing and vacuum forming technology to make any shape elbow, reducer, or transition piece of clear acrylic.

Photo 7 Detailed Acrylic Fabrication

Low water testing has been requested to determine how low the intake can operate. During this testing special attention will be paid to surface vortex activity. Experience has shown that these can travel long distances in suction piping as shown in the photo below.

Photo 8 Surface Vortex Traveling Through Horizontal Piping

Narrow channels gates can generate non-uniform approach flow. Any small variation in the uniformity of the approach flow can intensify the floor vortex activity which can easily travel through the suction piping and to the impeller location. An example of this is shown in the photo below.

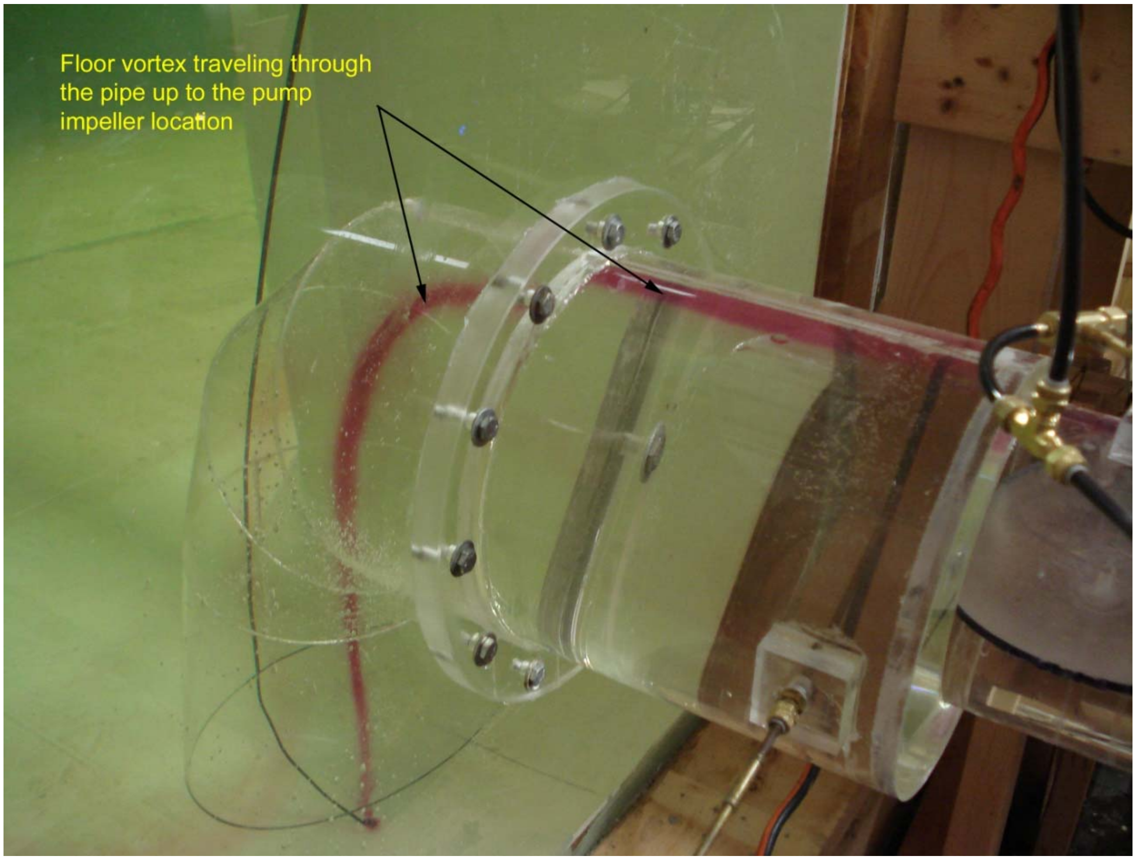

Photo 9 Floor Vortex Traveling Through the Suction Elbow

Non-uniform approach flow across the width of the pump bay can also cause rotation within the suction piping which can travel to the pump inlet. This can result in circulation in the piping that can impact the loading between each side of the impeller. The following photo shows dye being pulled from one side to the other in a similar suction arrangement.

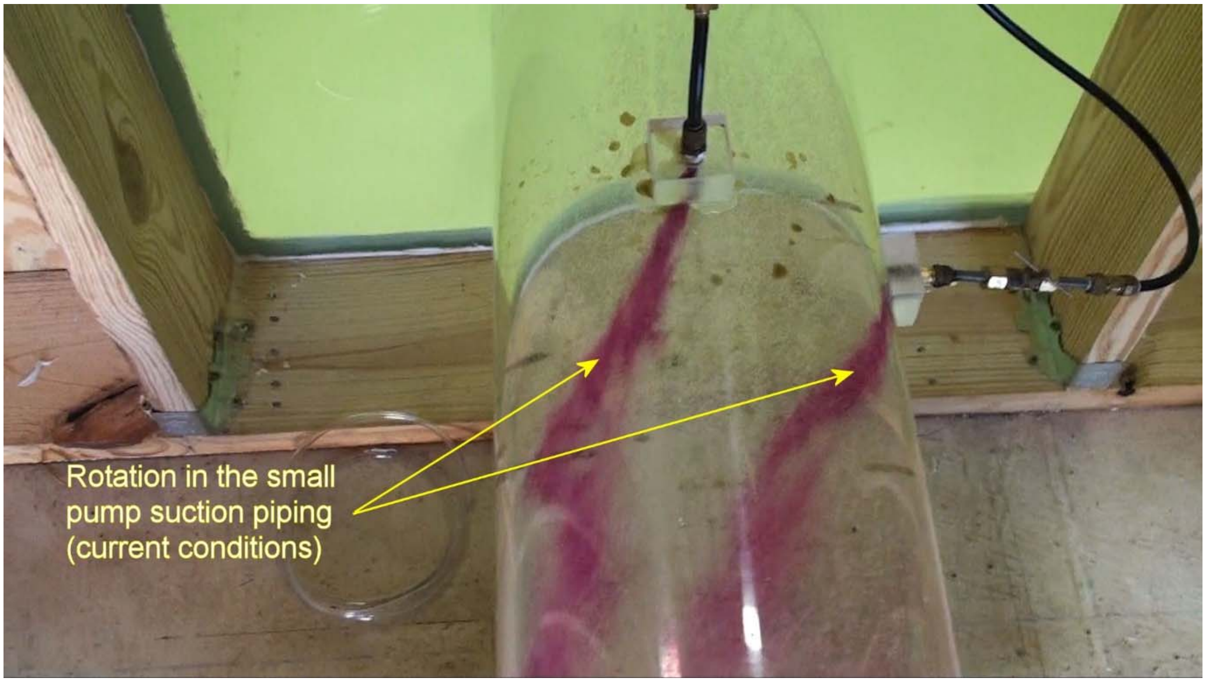

Photo 10 Circulation in Horizontal Suction Piping

The Hydraulic Institute recommends model studies for intakes with large total flows or non-uniform approach flow conditions. Given the lack of dividing walls, non-uniform orientation with the approach flow and concentrated channels, a physical model study would be required to meet Hydraulic Institute Standards. Several recent horizontal pump models have shown that the submerged vortex activity can easily travel through the suction piping and enter the pumps. Of greater concern however, is the possibility of a non-uniform velocity or uneven flow profile at the suction elbow. This often generates swirl within the suction piping that can be intensified through the suction piping. The typical remedies include floor splitters, flow straightening vane within the suction piping or vortex suppression baskets installed under the pumps. These types of problems, as well as the remedial modifications are well suited for rapid development in a physical model.

The physical model will be used to investigate both the flow within the intake structure as well as the flow within the suction piping. It is essential that the entire length of suction pipe from the wall of the forebay to the suction flange of the pump be included in the model. If needed, remedial modifications will be developed which could be incorporated into the intake once the main structure is complete.

ASSUMPTIONS

The following assumptions were made during the preparation of this proposal:

1. Given the near symmetrical configuration of each side of the wet well, CEH recommends only modeling one half of the station. CEH recognizes that there is not exact symmetry as the sloping floor is not symmetrical to the pump location. However, the overall orientation,

pump spacing and sizes are symmetrical and we feel results can be extrapolated between sides.

2. Three (3) 36-inch and two (2) 30-inch pumps will be modeled in detail. CEH assumes the existing pump suction elbows will be re-used or will be the same size as the existing elbows.

3. The full width and length of one-half of the intake will be simulated. CEH will also model a portion of the clear wells upstream of the flumes so that approach flow conditions can be simulated. The entire clear wells will not be modeled in detail.

4. Velocities will be taken in one pump of each size at the impeller location.

5. Any modifications that are developed will be non-structural and no changes to the overall size, shape, depth or layout of the intake will be made. Changes to the overall suction piping will only be considered if absolutely necessary.

6. The suction piping will be instrumented with dye taps to visualize flow separation or disturbances in the elbow and elbow insert.

7. A standard 4-ft deep model basin will be used. At the

SCALE SELECTION

To obtain accurate results from a model study, there must be dynamic similitude between the model and the prototype. To satisfy this requirement, there must be exact geometric similitude. In addition, the ratio of the dynamic pressures must also be maintained. Strictly satisfying dynamic similitude requires a 1:1 scale model. This is usually not feasible, so some compromise is made. To accomplish this, geometric similarity is maintained and the dominant forces associated with the prototype are determined and maintained between the model and prototype.

The primary forces that affect fluid flow are viscosity, surface tension, velocity (inertial), pressure, gravity and elastic forces. In structures with a free surface, such as a pump intake, gravitational and inertial forces are far greater than the viscous and turbulent shear forces. Therefore, when modeling free surface structures, geometric similarity and the ratio of inertial to gravitational forces, or the Froude number, is maintained between the model and prototype.

Simply holding the Froude number constant violates the strict definition of dynamic similitude. However, if the model is operated within a high enough range of Reynolds numbers, viscous and surface tension scale effects may be minimized. The 2012 Hydraulic Institute Standards (HI) recommends that the minimum Reynolds number at the bell be greater than 6×10^4. Therefore, when choosing the model scale, it is necessary to ensure that the scaled flow rate will result in a high enough Reynolds number to minimize scale effects. It is common to be conservative and select a scale that results in a Reynolds number on the order of 1×10^5. In addition, dry-pit pumps with suction piping should be operated at a Reynolds's number which is approximately 1×10^5

within the suction piping to overcome viscous effects associated with pipe flow. Failure to maintain this similarity can result in invalid model results.

Based on the above discussion, a Froude scaled, undistorted and geometrically similar model, with a scale of 1:4 to 1:5 is proposed for this study (depending on the final pump suction sizes). At this scale, the Reynolds number will be at or close to $1x10^5$ at the suction elbow. This scale is subject to change slightly based on final design drawings and the availability of materials.

PERFORMANCE CRITERIA

It is proposed that the following acceptance criteria be used for this model study:

1. No organized free surface or submerged vortices greater than a Type 1 (general rotation) should be permitted at Froude scaled flow rates

2. Pre-swirl should be less than 2.5-degrees at the pump impeller location per best practice which exceeds HI Standards.

3. Time averaged velocities within the pump throat should deviate less than 10 percent of the cross-sectional area average velocity

4. Time-varying velocity fluctuations (turbulence) at a point within the pump throat should be less than 10 percent

INSTRUMENTATION AND DATA COLLECTION

The following data will be collected and recorded for each test:

1. Flow Rate – The total model flow rate will be determined with an ASME standard orifice meter. Individual pump flow rates will be measured with elbow meters calibrated in-situ or other suitable flow meters with an accuracy of +/- 2 percent or better.

2. Water Levels – The water level in the pump sump will be recorded with a point or staff gauge with an accuracy of 3 mm (.01 ft) or better.

3. Vortices – Vortex formation will be visually observed. Dye will be used to aid in the visualization of vortex formation. Digital photographs and video footage will be used to document vortex formation.

4. Velocities – Velocity fluctuations and turbulence levels will be measured at the entrance to one pump inlet for one pump. The velocity meter will be capable of measuring the axial component of the flow velocity and will have a repeatability of +/-

2-percent. The velocities will be measured on a constant radius, at 8 points around the pump throat.

5. Pre-Swirl – A swirl meter will be installed at the impeller location for each detailed model pump. Each swirl meter consists of 4 straight vanes mounted on a shaft with low friction bearings.

MODEL LIMITS

The upstream model boundary is assumed to be a portion of the influent channels (metering flume) discharging into the upper chamber. The downstream model boundary will be the suction flange of the pumps. The entire intake structure housing the pumps will be simulated. The model head box, floor, and sidewalls will be constructed with waterproof wood. The model pumps, intake piping and pump bells will be fabricated out of clear acrylic up to the impeller location. The additional piping will be fabricated out of PVC pipe.

The suction piping will be fabricated from PVC pipe. Valves will be used to control the individual pump flows as well as the total model flow. A pump will be installed downstream of the model pumps to re-circulate flow back to the model head box. Flow straightening devices will be installed as necessary to ensure that flow entering the model head box is uniform.

Friction losses within the model limits are negligible compared to form or boundary losses. Therefore, it is assumed that materials mentioned above will be appropriate for model construction. Model design drawings will be prepared and submitted to Arcadis for approval prior to construction. The overall model basin will be constructed with a tolerance of +/- 0.25 model inches. The model pumps will be constructed to within +/- 0.06 model inches.

TEST PROGRAM

The model testing will be carried out in four phases. The actual test conditions will be determined with additional input from the pump manufacturer, design engineer, and end user. Each phase is described below:

1. Baseline tests – Baseline tests will be conducted with the original intake design. It is anticipated that up to 6 baseline tests will be conducted and the data mentioned in the instrumentation and data collection section of this proposal will be collected during each test. The worst case conditions will be determined during this phase of testing. These tests will be used to determine the nature and severity of hydraulic phenomena occurring within the pump intake structure and the flow distribution between the screen channels. The model will be capable of simulating any combination of one to four pumps in operation at low and high water levels.

2. Modification Tests – Modification tests will be conducted and modifications will be performed to bring the pump intake within the performance criteria. All proposed modifications would be presented to Arcadis for approval. Approximately 2 weeks

have been allocated to modification testing. Changes will be limited to non-structural modifications only (i.e. the overall intake size and shape will remain unchanged).

3. Witness Test – Following modification testing, a one-day witness test can be held at Clemson Engineering Hydraulics facility to demonstrate the models with and without the proposed modifications. Preliminary modification drawings will be available at the witness test. Representatives from Arcadis are encouraged to attend this test. Travel costs associated with Arcadis attending this test are not included in this proposal.

4. Documentation Tests – Following the witness test, it is anticipated that up to 16 documentation tests will be conducted to document the performance of the pump intake with the recommended modifications in place. The cost of evaluating the performance of the intake with the proposed modifications is included in this proposal. The model will be capable of conducting 1.5 x Froude tests as well as minimum water level tests.

REPORTING

CEH will prepare a project report containing methodology, procedures, conclusions and recommendations, as well as all data and documentation acquired during the testing for each of the intakes. A draft report will be made available at the witness test. Raw video footage of the testing will be provided in DVD format.

SCHEDULE

At this time, it is anticipated that a witness test could be held approximately 8 to 10 weeks after receiving the Notice-to-Proceed. The final report will be issued approximately one week after the witness test. CEH will work with Arcadis to ensure all critical deadlines are met and if necessary revise the schedule to accommodate required due dates. A detailed schedule will be provided once an actual start date has been determined.

PERSONNEL

Dr. David Werth, Ph.D., P.E. will serve as the project manager and principal investigator for this study as well as the primary technical contact. Dr. Werth has conducted and managed over 500 physical model studies of pump intake structures. Dr. Werth will be responsible for all phases of this project including model design and construction, testing and data collection, modifications, reporting, and quality assurance.

Mr. Ken Davy will be responsible for model construction and will manage the model operation. Mr. Davy has been responsible for the construction and operation of over 300 hydraulic model studies of pump intakes and has extensive experience in pump sump modeling. Additional technicians are available and may assist in model construction and instrumentation under the direct supervision of Dr. Werth and Mr. Davy.

Mr. Matthew Havice, P.E. will serve as the project engineer. Mr. Havice holds a Masters degree in Applied Fluid Mechanics and has over 10 years of physical modeling experience and has worked on over 200 pump intake models. Additional technicians are available and may assist in model construction and instrumentation under the direct supervision of Dr. Werth and Mr. Davy.

CLEMSON ENGINEERING HYDRAULICS, INC.

Clemson Engineering Hydraulics, Inc. (CEH) was "spun-off" from the successful modeling program developed by Dr. Werth and Mr. Davy at Clemson University. The company was formed to provide a larger more efficient physical hydraulic modeling program. CEH has relocated their modeling program to a much larger and better equipped 19,000 ft^2 facility just a few miles from the previous hydraulics lab located at Clemson University. The facility is fully equipped and staffed with significantly more physical modeling capabilities than those previously available at the university.

If needed, the following vender information is provided:

Company Name: Clemson Engineering Hydraulics, Inc.
Tax EIN: 20-5871960
Mailing Address: PO Box 478, Sandy Springs, SC 29677-0478
Physical Address: 1046 Watkins Rd, Anderson SC 29625
Phone: 864-231-9585
Fax: 864-231-9588
Contact: Dr. David Werth, Ph.D., P.E.

COSTS

A separate attachment outlining the fixed price costs to conduct this study has been included for your review. This price includes the cost of all testing, including documentation testing to verify the performance with the proposed modifications in place.

CEH proposes the following invoicing schedule, but will be happy to negotiate if necessary:

- 100 % upon submittal of the final report (net 30 days)

Invoices not paid within 30 days are subject to interest from the 31st day at the rate of 1.5 percent per month (18 percent annum) but not to exceed the maximum interest allowed by law. In addition, CEH may, after giving 7 days written notice to client, suspend services without liability until the client has paid in full all amounts due on account of services rendered and expenses incurred including interest on past due invoices, or terminate services without liability. If there is a disputed amount on an invoice, client agrees to pay all undisputed amounts in the 30-day period. In the event that CEH places client's account in the hands of the attorney for collection, client agrees to pay CEH all fees and expenses, including attorney's fees.

Costs have been estimated with the assumption that Arcadis will provide all information required for the model study. Arcadis will be responsible for the accuracy and completeness of the information. The owner retains responsibility for integrating any recommendations into the final design. CEH is not responsible for implementation, construction, or operation.

CEH agrees to conduct this study based on commonly accepted physical modeling procedures as outlined in the 2012 Hydraulic Institute Standards, and provide such services on a best faith effort. CEH warrants that the study will conform to the 2012 Hydraulic Institute standards, as well as commonly accepted physical hydraulic modeling practices. CEH makes no other warranty, express or implied, and shall have no other liability to Client.

Clemson Engineering Hydraulics, Inc. looks forward to the opportunity to once again work with Arcadis. In the event that any of the assumptions or technical aspects of this proposal are invalid, or need clarification, please feel free to contact Dr. Werth at 864-231-9585 or by e-mail at dwerth@ceh-lab.com. We look forward to hearing from you.

Sincerely,

David E. Werth, Ph.D., P.E.
President, Clemson Engineering Hydraulics, Inc.

FIXED PRICE BUDGET

Hollywood

Simulate Five Pumps In Detail (one half of the station)

Fixed Price = $42,000

Optional Add-On Cost to Simulate Both Sides

Fixed Price = $20,000