TECHNICAL MEMORANDUM

MWH

TM 3.7 – Hydraulic Evaluation of Existing System

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INTRODUCTION

The City of Bend, Oregon (City) has contracted with MWH Americas, Inc. (MWH) to provide the City with a new computer model of its collection system and a revised Sewer System Master Plan. Task 1 of the Sewer System Master Plan Project developed a new computer model of the City's collection system. The new collection system model was developed using InfoSWMM and is replacing the City's existing HYDRA model. Technical Memorandum (TM) 1D/1E documented the model inputs and calibration of the model. This TM documents further model development and utilization of the model to evaluate existing conditions and the various alternatives to plan for future needs. The scenarios that were evaluated are:

- Existing sewer system with existing flows
- Existing sewer system (no new interceptors) with build-out flows
- New interceptors with build-out flows

Many options for design of new interceptors were evaluated in order to design a Master Plan to meet anticipated needs with the least long term cost and disruption of existing City services.

The terms "existing", "current", and "todays" used when referring to the sanitary sewage flow and physical sewer system refer to the City's sewer system as of May 2005, flows as of February 2005 and projected long-term needs based on the existing conditions as of May 2005, the period for which the most complete data for use in the modeling task was available and the flow monitoring was performed.

MODELING APPROACH

The modeling of various alternatives under current and build-out conditions was performed. The model provided output that described the flow rate, velocity and depth of flow in each of the modeled elements throughout the modeled flow period. This output was then evaluated to determine the elements that exceeded capacity. Modifications were then made to the network (i.e. increasing pipe sizes, modifying pump station operation, etc.) to provide additional capacity at points in the system where capacity was not adequate. The model was then run again to determine the changes that resulted from the modifications. This process was continued until the final results providing adequate capacity were obtained for each scenario.

There were many assumptions made as the model was developed and the system flows were determined for each parcel. These assumptions have been documented in other TMs throughout this project. The following sections provide some additional information specific to this effort.

Wet Weather Flow Development

The impact of wet weather flows were considered in the modeling of the system. Each final alternative was evaluated under a wet weather event to ensure that no overflows would occur in the system. Wet weather flows can be highly variable, as was observed during the storm event on December 30, 2005. During this storm event, the existing system capacity was exceeded resulting in multiple overflows throughout the City and at the Water Reclamation Facility.

It is important to use a storm event that is not excessive resulting in the system being sized for an event that will rarely occur. The Oregon Administrative Rules provide guidance for system wet weather capacity. This guidance is outlined in the Bacteria Standard and states that there must be capacity to provide for wet weather flows that are generated by a 5-year, 24-hour storm event. This type of storm is not typical on the east side of the Cascade Range. A more typical storm is a localized thunderstorm. For this reason, a few storms that occurred in the period between April and June of 2005 were evaluated. The April 23, 2005 storm shown in ***Figure 1*** is typical of one of these localized thunderstorms.

During this April 23, 2005 storm event, an additional total daily flow of 1-mgd was observed at the treatment plant. The plant flow resembled the intensity and duration of the storm. This peak occurred for a 2-hour period resulting in a peak flow of 4-mgd (maximum during this storm event). Based on this information an inflow pattern was developed for assessing the capacities of the sewer network to handle future wet weather situations. This was done by developing a wet weather flow hydrograph and incorporating it into the flows developed at each sub-basin. It is known that there are roof drains

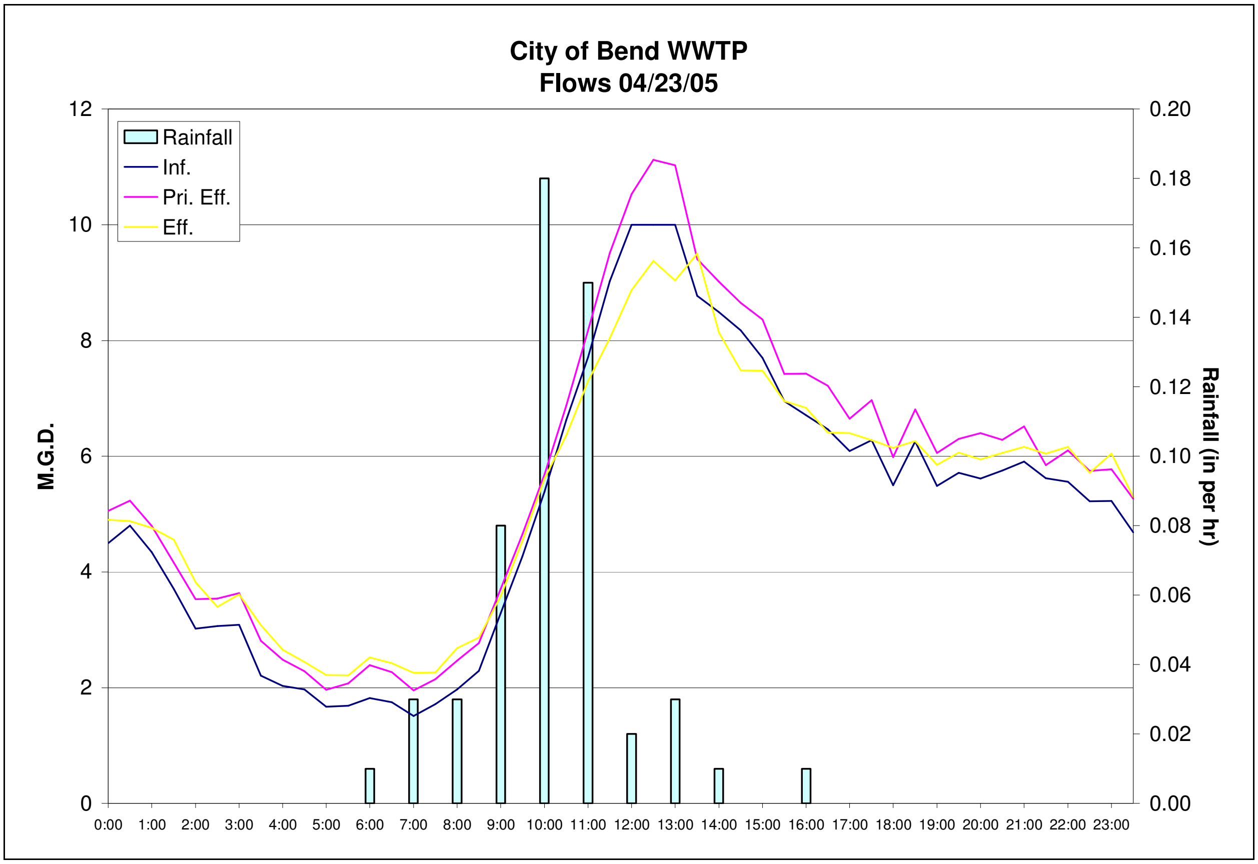

Figure 1 – April 23, 2005 Storm Event

connected to the sanitary system in the downtown area. With this factor, 35% of the total wet weather inflow was attributed to the downtown area and the remaining 65% was distributed among all other sub-basins. Storm flows were then distributed between sub-basins based on their area. In the capacity analysis for the future system it was assumed that the wet weather inflow under build-out conditions would be based on this same ratio as outlined above for the existing conditions.

Modeling of Capacity Improvements

The model was first run under dry weather flow conditions to evaluate if there was sufficient system capacity. The depth of flow (d) in each gravity sewer element was then compared to its diameter (D). A depth/diameter (d/D) ratio greater than or equal to 0.8 was defined as the maximum design depth for a gravity sewer. If this (d/D) ratio was greater than or equal to 0.8 at any time during the simulation, changes were made in order to improve sewer capacity. Depending on the particular layout of each pipe section, possible changes would be: increase the pipe diameter, adjust a contributing pump station flow rate (model variable flow pumping), or increase the pump station force main diameter.

As this analysis was performed, care was also taken to ensure that unnecessary capacity upgrades were not made. For instance, in highly developed areas, if d/D was between 0.8 and 0.9, the profile was examined closely and often no repairs were recommended. This was done to minimize disruption of city services due to unnecessary construction. Similarly, if d/D was only slightly greater than 0.8 and the model indicated long sections of pipe would need to be modified to improve flow, no changes were made.

In order to keep estimated repairs conservative, pipes were generally only increased by one size increment at a time. The model was then re-run to evaluate if these repairs were adequate. When increased capacity was modeled in a particular segment, this often increased flow to downstream segments due to the removal of the upstream bottleneck. Thus, segments not identified with deficient capacity in the initial run can become capacity deficient in the second run. Therefore, this process was repeated until all deficiencies were addressed.

Following the modeling of dry weather flow repairs, wet weather flows were incorporated into the model and the model was run again. During wet weather flows, pipes surcharging was acceptable (d/D => 1 is allowed). Under wet weather flows, the criteria used to determine system capacity deficiencies was the elimination of sewage overflows at manholes.

In scenarios that involved construction of new interceptors, these interceptors were sized to meet the same design criteria that was determined for the existing system. This criterion is:

- During peak dry weather flows d/D < 0.8
- During peak wet weather flows, no overflows
- Pump stations meet peak pumping capacity with largest pump out of service
- Force main velocity < 6 feet per second

The system model for the City is fairly large. A single model run can take between 45-minutes and one hour to run. This long run time made it impractical to run the entire system at once to assess various alternatives that impact only a portion of the sewer system. Therefore the City's Sewer system was divided into four modeling sections. They include Southeast, West, North, and Core. The system was divided into discrete section reflecting the actual division of flows from specific areas, where changes in influent flows or system configuration had little or no effect on the other sections. In each of the sections, the sub-basins were grouped together depending upon which interceptor they flow into. For example, all the sub-basins that flow to SE Interceptor are grouped together into one section and were modeled separately to size and evaluate the SE interceptor. After pipe sizing was performed on individual sections, the entire model was run to verify if the upsized pipe diameters were sufficient to handle the flow. The four sections accumulated flow was also modeled to evaluate the Plant Interceptor portion of the model.

The force main velocity criterion was only applied to new force mains; the model was not used to systematically evaluate force mains and pumps. As long as d/D and overflow criteria were satisfied, the pumps and force mains were not evaluated in the model. Instead, detailed calculations were performed for each individual pump and associated force mains. These results are presented in TM 3.8. Thus, the model provides information regarding fixes needed for the gravity portions of the system, and TM 3.8 provides information regarding the pumps and force mains. These two sources were used as input in the development of the Area Plans.

RESULTS OF HYDRAULIC EVALUATION

A number of scenarios were evaluated to develop the final system master plan. The first evaluation was to model the existing system under both daily peak dry weather flows and peak daily wet weather flows for the year 2005 to determine the existing capacity limitations. The existing system was then modeled under build-out flows. This was done to develop the capacity issues of the existing system at build-out. This was used as the Base Case condition. The rest of the modeling was done at build-out conditions to evaluate the various alternatives.

Evaluation Under Current Flows

In the existing flow scenario, the 2005 peak daily flows, both dry weather and wet weather were applied to the existing system in separate evaluations. There were no changes made to the existing system in this scenario. This scenario identified the capacity limitations that exist under the existing flow conditions. The existing system deficiencies are shown in ***Figure 2***.

This analysis showed that there are currently a few capacity deficiencies in the system. The most critical of these deficiencies are:

- Deficient capacity in the forcemain discharging from the Murphy Road Pump Station
- Deficient capacity at the discharge of the Westside Regional Pump Station
- Deficient capacity at the discharge of the Wyndemere and Sawyer Park Pump Stations

Each of these capacity limitations will be addressed in the Master Plan.

Evaluation Under Build-Out Flows Without Interceptors

In this scenario, build-out flows, both peak dry weather and peak wet weather, were applied to the existing system. No modifications were made to the existing system. Flows from currently unsewered and undeveloped basins were placed into the system at an appropriate point. The objective of this scenario was to get an indication of how extensive system deficiencies would be without the addition of new interceptors. Only one model run was made in this scenario and no upgrades were made of any capacity limitations. Therefore, the result of this analysis only shows a portion of the system capacity problems. At each point where a capacity limitation occurred, there is a flow restriction to downstream flows and possibly an overflow, resulting in flows leaving the system. The effort was not done to identify all of the capacity limits in the system, because it was determined that the capacity limits identified in the first model run were so excessive that continuing with this scenario had no merit. The system deficiencies identified in this model run are shown in ***Figure 3***.

- An estimate was made of the number of repairs that would be required, including the portions of the system where the capacity limitations were not determined. To do this, the deficiencies identified in the model alternative “Westside Scenario 1” (described in detail later in this TM) were used as a similar case to determine the extent of repairs that would be needed. It was assumed that the distribution of final pipe sizes needed would follow the same pattern. For example, the deficiency for 8-inch pipe would need to be increased to 10-inch or greater. The initial deficiencies that are determined are not the total extent of the deficiencies, as described above. There will be additional downstream deficiencies occurring as bottlenecks and overflows.

FIGURE 2

FIGURE 3

As the initial deficiencies are fixed by upsizing the deficient line segment, the capacity in these segments will be increased. The model will then be run with the new pipe sizes. The flows from the intial run will then pass do downsteam segments and any overflows will be contained in the system. This will result in higher system flows. As these deficiencies are identified and fixed using an iterative process of additional model runs and repair of system deficiencies more deficiencies than identified in the initial model run will be identified. Thus, the initial deficiencies depicted in ***Figure 3*** underestimate the total length of pipe that needs to be fixed. Based on experience with other build-out scenarios, it was estimated that an additional 20% system capacity limitations would be found. Thus, all lengths were increased by 20% to represent the potential deficiencies that could be possible with the system. The results of this analysis are summarized in ***Table 1***.

This analysis shows that there are 157,747-feet or 29.9-miles of the existing gravity system that are deficient. This is 10% of the existing gravity system.

Evaluation of Master Plan Alternatives

A number of alternatives were evaluated to develop the final alternatives that have been recommended in the Master Plan. Each of these alternatives included a new interceptor or a combination of new interceptors to redirect existing and future flows from the existing core system. The main elements of the systems that were evaluated include:

- Parallel Plant Interceptor – provides additional capacity from the City to the Water Reclamation Facility (WRF)
- Southeast Interceptor – Provides service to the east, south and southeast Bend areas, relieving capacity limitations in the existing core system
- Westside Interceptor – Redirects flows generated on the west side of the Deschutes River and pumped by the Westside Regional Pump Station to the North Interceptor, relieving capacity limitations in the existing core system
- Reduction of westside flows by redirecting the Shevlin Commons, Awbrey Glen, and three undeveloped westside sub-basins to the North Interceptor
- Redirect Sawyer Park and Wyndemere Pump Stations to the new Westside Interceptor relieving capacity limitation in the exiting core system

North Interceptor – Provide service to the undeveloped areas on the north end of the City, the new Juniper Ridge development and basins on the northwest side of the City

The parallel Plant Interceptor parallels the existing plant interceptor and adds capacity to accommodate projected growth within the Bend planning area. It is planned to be intertied with the existing interceptor to maximize flexibility in operations and allow for diversion during times of intensive maintenance. All future flows will be conveyed by one or both of the plant interceptors.

The new interceptor elements that were evaluated and incorporated into the Master Plan are shown in ***Figure 4***. In this figure, the sub-basins are shaded according to whether their flow goes to the Southeast Interceptor, West Interceptor, North Interceptor, or Core System (existing interceptor). This figure also shows the location of recommended repairs needed to meet the projected build-out flows. Repairs for Shevlin Commons and Awbrey Glen, are not shown on this figure. This is because these stations are removed from service with their flows redirected to the North Interceptor in the Master Plan. Currently Flows from Shevlin Commons and Awbrey Glen flow into Westside PumpStation but in the Master Plan it was assumed that it is more cost effective to divert flows from these two pump stations to the North Interceptor through the proposed Trunk sewers However, other scenarios where Shevlin Commons continues to flow into the Westside Pump Station indicated that no capacity upgrades were needed for Shevlin Commons but some capacity upgrades were needed in the Awbrey Glen basin. In addition, capacity upgrades will be needed in the Awbrey Glen pump station and the gravity sewer downstream of the station discharge if it continues to flow through the Westside pump station.

Table 1
Estimated Gravity Pipe Repairs Needed To Meet Build-out Flows Without New Interceptors

Existing Diameter (inches)	Estimated Diameter at Buildout (inches)	Estimated Length at Buildout (feet)
6	8	172
8	10	29,898
	12	16,131
	15	7,017
	21	656
	24	471
	27	1,065
10	12	7,130
	15	6,488
	18	4,152
	27	417
12	15	16,936
	18	4,049
	21	534
15	18	4,738
	21	5,275
	24	388
	27	609
18	24	5,470
21	24	3,902
	27	4,395
24	30	5,591
27	30	1,480
	36	4,768
30	36	895
	42	2,692
36	48	13,547
42	48	8,881
TOTAL		**157,747**

INSERT Figure 4 – New Interceptor Elements

SE Interceptor with Build-out Flows

The Southeast Interceptor alignment along 27th Street was added to the model. Each point where a sub-basin on the east side of 27th Street crossed the interceptor, the sub-basin flows were assigned to the interceptor at the points where the sewers intersected. The sub-basins that will be served by the SE Interceptor and the interceptor pipe sizes are shown in ***Figure 5***. The specific alignment of the SE Interceptor is discussed in detail in TM 3.9 – Interceptor Evaluations. Flow from appropriate sub-basins was directly input into the interceptor at the nodes show in the figure. The area served by the gravity system upstream of the current Murphy Road Regional Pump Station was diverted into the upstream end of the Southeast Interceptor. In the model, these pipes were disconnected from their current northern flow, and connected to the upstream end of the Southeast Interceptor. All the "grayed-out" portions of the model are turned off for this scenario. This scenario was run iteratively to determine optimum pipe sizes for the Southeast Interceptor under build-out conditions. The SE Interceptor pipe lengths and sizes that were modeled are shown in ***Table 2***.

Table 2
Recommended SE Interceptor Pipe Sizes

Diameter (inches)	Length (feet)
18	5,962
24	40,330
36	3,702
Total	**49,994**

Westside Pump Station Basin Scenarios

Four scenarios were examined in order to evaluate the flows generated at build-out on the west side of the Deschutes River that will flow to the Westside Regional Pump Station. All Westside scenarios include a new Westside Interceptor. This interceptor begins with a forcemain approximately 3,000 feet long, followed by a gravity sewer approximately 21,000 feet long, discharging into the North Interceptor west of Juniper Ridge along Highway 97. There may be slight variations depending on the alignment selected, but this will not affect the final results. Constructing the new Westside Interceptor will redirect flow away from the existing core system and significantly reduce the deficiencies that will occur in there.

In some of Westside scenarios that were evaluated, extensive capacity upgrades in the Westside gravity system will be required to handle the build-out flows. Therefore, various scenarios were evaluated that redirected the flows from various sub-basins in the basin. These flows were routed to the North Interceptor. This demonstrated that rerouting flows can significantly reduce the number of capacity limitations that would occur in the Westside Pump Station basin.

Westside Scenario 1

In this scenario, Shevlin Commons and Awbrey Glen continue to flow through the Westside Pump Station basin. In addition, flow from western basins outside the UGB is directed to the Westside basin. In order to handle the increased flows, extensive system capacity upgrades are needed. The capacity deficiencies are shown in ***Figure 6***. In this and subsequent figures, sub-basins flowing through the Westside Pump Station basin are shaded differently to indicate the sub-basins that flow through the Westside basin and those that flow directly into the North Interceptor.

INSERT Figure 5 – SE Interceptor

INSERT Figure 6 – Westside Basin Scenario 1 Deficiencies

Westside Scenario 2

This scenario is similar to Westside Scenario 1, except that in this scenario it is assumed that Shevlin Commons and Awbrey Glen are redirected into the North Interceptor, reducing flows through the Westside basin. The number of deficient capacities are slightly reduced in this scenario when compared to Westside Scenario 1. Extensive capacity upgrades will still be required. The capacity deficiencies are shown in ***Figure 7***.

In this and subsequent Westside basin scenarios, flows from the Sawyer Park and Wyndemere Pump Stations have been redirected the new Westside Interceptor, instead of flowing through the downtown core system. Although this does not adversely impact Westside basin flows, it benefits the downtown core system. The impacts on the downtown cores system are discussed in a later section.

Westside Scenario 3

This scenario is also similar to Westside Scenario 1. In this scenario Shevlin Commons and Awbrey Glen continue to flow through the Westside basin as in Scenario 1. The flow reduction in Westside Scenario 3 is accomplished by directing three of the westernmost sub-basins into the North Interceptor. The initial model run for Westside Scenario 3 identified extensive capacity deficiencies in the gravity system. Based on the results of Westside Scenarios 1 and 2, it was concluded that the required capacity upgrades in Westside Scenario 3 would be extensive. This scenario was evaluated and was not recommended. No figure was generated for this scenario.

Westside Scenario 4 (Preferred)

In this scenario, the Shevlin Commons and Awbrey Glen Pump Stations and three currently undeveloped sub-basins were directed to the North Interceptor. This decreased flows through the Westside basin resulting in significantly reduced capacity deficiencies required in the Westside basin. These capacity deficiencies are shown in ***Figure 8*** Westside Scenario 4 was selected as the recommended option for the drainage area to the Westside Regional Pump Station and the North Interceptor in the Master Plan. This scenario was used as the configuration for the Westside Interceptor when the entire system was run with all other interceptor elements. This effort will be discussed later in this TM in the Hydraulic Evaluation Summary section.

INSERT Figure 7 – Westside Basin Scenario 2 Deficiencies

INSERT Figure 8 – Westside Scenario 4

North Interceptor

A new interceptor is planned to serve the existing northern areas of the City. All flows from northern sub-basins that can flow by gravity into the North Interceptor were assumed to do so. This included all undeveloped sub-basins outside the UGB as well as some currently developed sub-basins within the UGB. The sub-basins contributing to the North Interceptor are shown in ***Figure 9***. In the final Master Plan recommendation, the North Interceptor includes flows from all of the sub-basins from the proposed Juniper Ridge Development, the Shevlin Commons and Awbrey Glen Pump Stations and three currently undeveloped sub-basins located south of Shevlin Park on the west side of the City

In addition to the basins directed to the North Interceptor, the flows from the Sawyer Park, Wyndemere and Westside Regional Pump Stations were redirected into the North Interceptor through the proposed Westside Interceptor. The redirection of all of these flows to the new Westside Interceptor provided capacity relief to the existing downtown core system, minimizing the capacity upgrades that would be necessary in that system.

The model was used to optimize the size of the North Interceptor. The sizes and flows in the interceptor are shown in ***Figure 9***. A detailed analysis of the North Interceptor is provided in TM 3.9 – Interceptor Evaluations.

Core System Evaluation

All sub-basins that were not assigned to the Southeast, Westside or North Interceptors were directed to Core System Basin. Two Core System Basin scenarios were run. In the first scenario, the Sawyer Park and Wyndemere Pump Stations discharges were not changed and they continued to flow through the core system. This analysis showed that there were a large number of capacity deficiencies downstream of Sawyer Park and Wyndemere. These deficiencies are shown in ***Figure 10***.

The discharges from the Sawyer Park and Wyndemere Pump Stations were then redirected away from the core system basin by connecting them to the proposed Westside Interceptor. A second Core System Basin scenario was then run without these flows. The results of this scenario showed that there were very few capacity upgrades required downstream of the Sawyer Park and Wyndemere Pump Stations. The results of this analysis are shown in ***Figure 11***. The reductions in the required capacity upgrades to the Core System Basin were significant enough to make this the preferred option. Therefore, the discharge from the Sawyer Park and Wyndemere Pump Stations along with the discharge from the Westside Regional Pump Station will be removed from the Core System Basin by redirecting them to the North Interceptor through the proposed Westside Interceptor.

Plant Interceptor System and Siphons

A new Plant Interceptor parallel to the existing interceptor is proposed. The Southeast Interceptor will connect to the North Interceptor southeast of Juniper Ridge. From there, the

INSERT Figure 9

INSERT Figure 10 – Core System without Sawyer Park and Wyndemere PS capacity deficiencies

INSERT FIGURE 11

new Plant Interceptor flows parallel to the existing interceptor to the siphon box. At this point, the flows from the two interceptors will be joined in an expanded siphon box. The existing siphon is made up of two lines until just prior to the headworks where they combine into a 30-inch line that continues to the headworks.

A new headworks will be constructed at the treatment plant. As part of the new headworks, there will be a flow diversion box constructed. It is being recommended in the Master Plan that the two existing siphons not be combined into the common 30-inch line, but continue to flow separately to the new headworks diversion box. A new 48-inch siphon is recommended in the Master Plan to connect the expanded siphon box to the new headworks diversion box. This will provide three independent siphon lines between the siphon box and the headworks diversion box. This configuration has been modeled as shown in ***Figure 12***

In addition to the new siphon, the model has been configured with the SE Interceptor connecting to the existing Plant Interceptor at the point where it crosses the interceptor. This configuration allows flows from the Core System Basin to be diverted to the new Plant Interceptor.

Awbrey Glen Basin

The sequence of modeling the Westside Pump Station Basin did not provide for adequate modeling of the Awbrey Glen basin and Pump Station. For this reason, a separate evaluation of this system was performed. The results of this evaluation show that there are capacity deficiencies in the Awbrey Glen gravity system under build-out flows. There are also capacity deficiencies in the gravity system downstream of the existing Awbrey Glen force main discharge. If Awbrey Glen flows are not diverted to North Interceptor, upgrades to the gravity system downstream of the discharge need to be made. The results of this analysis are shown in ***Figure 13***.

HYDRAULIC EVALUATION SUMMARY

A number of scenarios were modeled to determine capacity deficiencies that would develop under build-out flows. The scenarios were refined to develop a Master Plan that included four new interceptors: Parallel Plant Interceptor, North Interceptor, SE Interceptor and Westside Interceptor. The final modeled scenario provided the deficiencies that will exist in the system when build-out flows are experienced in the system that is recommended in the Master Plan. These deficiencies are shown in ***Figure 14***

The deficiencies that have been identified in this modeling effort have been evaluated further. The results of this evaluation are discussed in TM 3.10 – Long-Term Conveyance Plan.

FIGURE 12

INSERT FIGURE 13

INSERT FIGURE 14

RECOMMENDATIONS FOR FURTHER EVALUATION

The level of effort that was done for this hydraulic evaluation was appropriate to evaluate the alternatives for this planning level analysis. Additional modeling is recommended to optimize the system during predesign. The following evaluations are recommended:

- The siphon system can be optimized. It may be possible to adjust the invert elevations to improve the overall flow distribution between the siphons. .

The eastern portion of the North Interceptor required careful adjustment of invert elevations to maintain adequate slope to handle flows. A careful analysis of this system needs to be done during final design to confirm these slopes.

- The alignment of the Westside Interceptor needs to be confirmed. Once this is done, the hydraulics and gravity system size needs to be confirmed.