DRAFT TECHNICAL MEMORANDUM

DATE: October 16, 2013

PROJECT: 12-1354.405

TO: City of Bend, Oregon

FROM: Murray, Smith & Associates, Inc., Clearwater Engineering Group, LLC.

RE: Alternative Project Unit Cost Development and Cost Analysis

INTRODUCTION

This section summarizes the approach used in development of costs and lowest cost optimization for collection system alternatives within the City of Bend (City) Collection System Master Plan (CSMP) Update 2013.

Project unit costs derived in this section are the basis for cost curves used in building an optimization model and capital cost determination for the City's wastewater collection system, Section X - Analysis and Optimization. Project unit costs will be used for development of the final Capital Improvement Program (CIP) budget(s) associated with the CSMP recommended for adoption by the City, Section X - Capital Improvement Program.

The Operation and Maintenance (O&M) costs are the basis for the annual cost to operate and maintain components of the collection system.

The cost analysis and Equivalent Uniform Annual Cost (EUAC) portion describes the methods and inputs of the project unit costs and O&M costs for the EUAC of alternative optimization projects.

COST BASIS

All costs identified in this section reference US dollars. The *Engineering News Record* Construction Cost Index (ENR CCI) basis is 9430 (Seattle, April 2013).

Project unit cost estimates were prepared in accordance with the guidelines of American Association of Cost Engineers (AACE) International, the Association for the Advancement of Cost Engineering. AACE International's Class 5 Estimate is described as follows:

"CLASS 5 ESTIMATE (Typical level of project definition required: >0 to 2 percent of full project definition.)

Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended. Class 5 estimates are prepared for any number of strategic business planning purposes, such as, but not limited to, market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc."

The expected level of accuracy for this class of estimate are -20 to -50 percent on the low side and +30 to +100 percent on the high side.[1]

The unit project cost estimates have been prepared for the purpose of evaluating project alternatives and budgeting for master plan implementation. Unit project cost estimates were prepared from information available at the time of the estimate and are based on a low level of project definition. Unit project costs developed herein produce "rough cost estimates" consistent with the definition of OAR 660-011-0005(2) and OAR 660-011-035. The true cost and resulting feasibility of a planned project will depend on the actual labor and material costs, competitive market conditions, site conditions, final project scope, implementation schedule, continuity of personnel and other variable factors. Therefore, the actual unit project costs will vary from the estimates presented here. Because of these factors, project feasibility, benefit/cost ratios, risks and funding must be carefully reviewed prior to making specific financial decisions or establishing project specific budgets.

Collection System Components Subject to Project Unit Cost Analysis

Project unit costs were developed for two classes of collection system components: linear assets and non-linear assets.

Linear assets include:

- Trenched New Gravity Sewers and Interceptors
- Trenched Gravity Sewer and Interceptor Upgrades
- Trenched In-line Storage
- Trenched Siphon Structures
- Trenched Force Mains
- Trenchless River/Railroad/Highway Crossing Force Mains
- Trenchless Canal/Railroad/Highway Crossing Gravity Sewers

[1] AACE International Recommended Practice No. 18R-97 - Cost Estimate Classification System - As Applied in Engineering, Procurement, and Construction for the Process Industries, 2005.

- Trenchless Gravity Sewer Upgrades
- Trenchless Gravity Sewer Rehabilitation

Non-linear assets include:

- New Lift Stations
- Existing Lift Station Upgrades
- Off-line Storage
- Satellite Treatment Facilities

Cost Items Excluded

The following elements were not included in the development of unit project costs:

- Collection system studies, planning or modeling
- Borrowing or finance charges during the planning, design or construction of assets
- Wet weather or emergency storage at lift stations
- Groundwater control during asset construction; Groundwater is not a typical cost factor for underground and above ground constructions in Bend, Oregon for specific capital improvement projects identified in close proximity to the Deschutes River or Tumalo Creek, a cost factor adjustment was considered for optimization refinement. (it is assumed that Canal crossings are constructed during non-irrigation season)
- Electrical distribution line extensions, service lines, or transformers as needed to serve in-line storage facilities, lift stations, off-line storage facilities, or satellite treatment facilities (it is assumed that the utility provider will construct these facilities with the expectation of cost recovery through user charges)
- Wash-down facilities for off-line storage facilities
- Improvements to conveyance, pumping, storage, or satellite treatment facilities in response to changes in regulatory standards or rules
- Remediation or fines associated with collection system overflows
- Decommissioning or rehabilitation costs at the end of life of an asset

PROJECT UNIT COST DEVELOPMENT

Project unit costs were developed through a progression of steps and multiple methodologies. The steps include development of component unit costs, construction unit costs and, finally, project unit costs. The methodologies will be discussed throughout this section.

The component unit cost includes the sum of materials, labor and equipment of easily identifiable features of a project. The construction cost is the sum of component unit costs and mark-ups to determine the probable cost of construction (i.e., the contractor bid price).

The project unit cost is the sum of construction unit costs with additional cost allowances for engineering, legal and administration fees to determine the total project cost to the City.

Component Unit Cost and Cost Approach

To develop project unit costs, one of three approaches was used;

Approach 1. Reference component costs of specific work where readily available from cost estimating sources such as *RS Means*. Component costs for specific work were developed from the sum of material, labor and equipment costs for individual elements that make up the specific work. In some cases, an estimate of component cost for construction of specific work was solicited from construction contractors with recent and applicable experience with the subject technology, means, methods and materials.

Approach 2. Reference available data for the total cost of construction for similar projects undertaken in the United States within last 15 years. Available construction cost data was escalated from the year the project was bid/constructed to the year 2013.

Approach 3. Reference component cost of construction data from *(City of Bend) Collection System Master Plan Final Report, MWH, July 2007* and *Collection System Master Plan Addendum No. 4, CH2MHill, May 2011.* Component costs of construction were escalated from the year of publication to 2013.

Construction Unit Cost

Construction unit cost was developed from the three approaches and sums the cost of component unit costs plus mark-ups. Mark-ups were applied differently depending on cost approach, and a summary is provided in Table 4-1. When mark-ups are not applied to obtain the construction unit cost, it is because they are included in component unit cost.

Approach 3 construction unit costs were compared to recent and similar projects constructed in the Central Oregon area and adjustments were made to component costs as appropriate to align costs with the available record of bid prices to develop construction unit cost. Approaches 1 and 2 were already aligned to construction costs due to the basis of the component cost approach.

Construction Mobilization

Mobilization mark-up accounts for the cost of the contractor's administrative and direct expenses to mobilize equipment, materials and labor to the work site.

Traffic Control

Traffic control mark-up accounts for the cost of signage, flagging and temporary barriers, street widening, pavement markings, lane delineators and lighting at flagging locations. The level of effort and cost for traffic control depends on the size and scope of a project, and local conditions at the time of construction.

Erosion Control

Erosion Control mark-up accounts for materials and practices to protect adjacent property, storm water systems, and surface water in accordance with regulatory requirements. The level of effort and cost for erosion control depends on the size and scope of a project, and the local conditions at the time of construction.

Construction Contractor Overhead and Profit

This mark-up accounts for the contractor's indirect project costs and anticipated profit.

Construction Contingency

Collection system improvements considered in planning level evaluations were subject to a contingency to account for the cost of uncertain and unanticipated factors. These factors include unanticipated utilities, relocation and connection to existing infrastructure, minor elements of work not addressed in component unit cost development, details of construction, changes in site conditions, and variability in construction bid climate. The sum of component unit cost was marked up by the construction contingency.

A summary of mark-ups is provided in Table 4-1.

Table 4-1
Mark-ups on Component Unit Costs to Obtain Construction Unit Cost by Approach

Description	Approach 1 Project Mark-up	Approach 2 Project Mark-up - Linear	Approach 2 Project Mark-up - Non-Linear	Approach 3 Project Mark-up
Construction Mobilization	10 %	10 %	Included in Component Cost	Included in Component Cost
Traffic Control	8.4%	8.4%	Included in Component Cost	8.4%
Erosion Control	0.8%	0.8%	Included in Component Cost	0.8%
Construction Contractors Overhead and Profit	15 %	Included in Component Cost	Included in Component Cost	Included in Component Cost
Construction Contingency	30 %	30 %	Included in Component Cost	30 %

Project Unit Cost

To develop project unit cost, mark-ups for engineering, and the Owner's legal and administration were added to the construction unit cost developed using all three approaches and are summarized in Table 4-2. All project unit costs summaries are provided in Appendix 4A-Supplemental Information for Project Unit Cost.

Engineering

Construction Unit Cost was subject to mark-up for engineering to account for the cost of professional services associated with survey, design and production of contract documents. The mark-up for engineering includes the cost of construction period support services generally consisting of submittal review, supplemental information and change evaluation.

Owner's Legal and Administration

Construction unit cost was subject to mark up for Owner's legal and administration to account for the direct and indirect cost of project management staff, finance and purchasing assistance, legal services, and owners testing agency deployed during construction.

Table 4-2
Mark-ups on Construction Unit Cost to Obtain Project Unit Cost

Description	Linear Asset Project Mark-up	Non-linear Asset Project Mark-up
Engineering	20 %	20 %
Owners Legal and Administration	10 %	10%

Cost Factor

Cost factors were applied to specific projects in the optimization cost model and were applied to account for preconstruction investment in design development, site specific conditions, and other factors that make the base project unit cost non-representative of a the anticipated cost of a specific project. The base project unit cost for specific projects (project cost without addition of a cost factor) was derived from the base cost tables and cost curves and multiplied by the cost factor.

S.E. Interceptor

(Gravity Sewer from Murphy Lift Station to existing plant interceptor using the 27th St. alignment)

A cost factor of 0.85 was applied to the estimate of initial project cost. The cost factor accounts for the estimated preconstruction investment that has been expended on design development, Right-of-Way (ROW) acquisition, and administration. The cost factor was not applied to future replacement cost. The cost factor only applies to segments of the SE Interceptor on the alignment where design has been completed, and only to segments that have been designed but have not been constructed.

North Area Gravity Sewer

(Gravity Sewer from Hwy 20 to existing Plant Interceptor referencing design alignment YR2000)

A cost factor of 0.95 was applied to initial project cost. The cost factor accounts for the estimated preconstruction investment that has been expended on design development, ROW acquisition, and administration. The cost factor was not applied to future replacement cost. The cost factor was only applied to segments of the North Area Gravity Sewer (North Interceptor) on the alignment where design is completed, and only to segments that have been designed but have not been constructed.

Westside Lift Station

A cost factor of 1.5 was applied to the estimate of initial project cost. The cost factor accounts for construction difficulty associated with small site size, relatively high flow, constrained roadway frontage, proximity to river, and need to maintain service in existing facilities during construction of a new lift station.

Colorado Lift Station

A cost factor of 1.0 was applied to the estimate of initial project cost. The cost factor accounts for degree of difficulty associated with small site size, constrained site access, proximity to river, proximity to high use parkland, need to maintain service in existing facilities during construction of a new lift station, estimated preconstruction investment that has been expended on design development, ROW acquisition, and administration. The Colorado Lift Station cost factor is equal to 1.0 because the degree of difficulty is offset by the estimated level of preconstruction investment that has been expended on design development.

LINEAR ASSET PROJECTS

Linear Asset Project Unit Cost Assumptions

Assumptions applied in development of linear asset project unit costs are described here.

Rock Excavation

Project unit costs developed using Approach 1 were developed with the cost of rock excavation included. It was assumed that blasting and rock excavation will be required for all new trenching extending to depths greater than four feet below existing ground surface. The cost of rock excavation was assumed to be included in component unit costs developed using Approach 3 (e.g., trenched in-line storage and trenched new gravity sewers and interceptors) by comparison against actual bid tabs.

Manholes and Air & Vacuum Valves/Clean-outs

New gravity sewer and gravity sewer upgrade project unit costs include costs for new manholes. Force mains include installation of air & vacuum valves or clean-outs within access vaults.

Project unit cost for gravity sewers and interceptors includes manholes spaced 300 feet on center along the length of the asset. While the City of Bend Standards and Specifications allow a 500-foot maximum spacing, the 300-foot spacing makes allowance for closer spacing at roadway curves, changes in pipe slope or elevation, pipe junctions, and special applications. Manhole project unit costs were developed using Approach 3. Appendix 4A presents material and installation costs for manholes with respect to gravity sewer diameter and depth.

Air & vacuum valves, and clean-out assemblies on force mains are products and configurations in accordance with the City of Bend Standards and Specifications. Unit costs for force mains include air & vacuum valves/clean-out assemblies are spaced 500 feet on center along the length of the asset per the City of Bend Standards and Specifications. Air and vacuum valves, and cleanout assembly project unit costs were developed using Approach 2. Appendix 4A presents the material and installation costs for air and vacuum valves or clean-outs with respect to force main diameter.

Surface Restoration

Project unit costs for linear assets are differentiated according to surface restoration requirements. For development of specific project costs, surface restoration was assigned to linear assets according to designations; Dirt or Gravel Surface, Local Street, and Arterial Roadway. Each designation is associated with assumptions for surface demolition and disposal, aggregate base and asphalt replacement, overlay, curb and gutter, striping, etc. Project unit costs associated with surface restoration were developed using Approach 3, are additive to other project unit costs and are shown in Appendix 4A.

Dirt or Gravel Surface

Surface restoration cost associated with Dirt or Gravel Surface includes grading of backfill over the trench section and construction of an aggregate access way to facilitate operations and maintenance. Dirt or Gravel Surface restoration cost is associated with over-land alignments where no existing roadway is present or where an existing gravel roadway would be reconstructed in association with a linear asset project.

Local Street

This additional cost is associated with Local Street alignments as designated by City roadway mapping. Surface restoration cost associated with a Local Street includes removal of asphalt and replacement of aggregate base and asphalt over the trench section. At greater pipe diameter, the project unit cost of restoration assumes increased removal and replacement costs in relation to a wider trench.

Arterial Roadway

This additional cost is associated with Arterial Roadway alignments. Surface restoration cost associated with Arterial Roadway includes removal of asphalt and replacement of aggregate base and asphalt over the trench section. At greater pipe diameter the project unit cost of restoration assumes increased removal and replacement costs in relation to a wider trench.

Linear Asset Project Unit Cost

Trenched New Gravity Sewers and Interceptors

Project unit costs for trenched new gravity sewers and interceptors were developed with cost as a function of pipe diameter and depth using Approach 3. Cost tables for Trenched New Gravity Sewers and Interceptors appear in Appendix 4A. Project unit costs for this category of projects are applicable to new gravity sewer pipe installed in new trenches. This category of work is used to reroute flow to address hydraulic deficiencies in existing pipe or to provide service to areas not presently served.

Project unit costs are based on PVC pipe for gravity sewers and interceptors less than 18 inches in diameter and reinforced concrete pipe for gravity sewers and interceptors 18 inches in diameter and larger, consistent with the *Collection System Master Plan Final Report, MWH, July 2007*. Open cut trenching is assumed for all new gravity sewers and interceptors considered in the optimization process and advancement to the CIP list unless identified specifically as a project using trenchless technology. Project unit cost development includes no bypass pumping or connection of services. Manholes are included in the cost of new gravity sewers and interceptors.

Trenched Gravity Sewer and Interceptor Upgrades

This category of work is used to upsize a pipe to address hydraulic deficiencies or replace a pipe in kind to address condition deficiencies. Project unit costs for this category are applicable to new pipe in existing trenches. Trenched gravity sewer upgrade project unit costs were developed with cost as a function of pipe diameter and depth using Approach 3. Project unit cost development was similar to that for new gravity sewers and interceptors; however, project unit costs include allowance for bypass pumping and reconnection of existing services. Trenched Gravity Sewer and Interceptor Upgrade project unit cost tables appear in Appendix 4A.
Open cut trenching is assumed for all gravity sewer and interceptor upgrades considered in the optimization process and advancement to the CIP list unless identified specifically as a project using trenchless technology.

A bypass pumping cost of $17.00 per foot on pipes 24 inches in diameter and smaller, and $21.00 per foot on pipes larger than 24 inches in diameter is included in the project unit cost for Trenched Gravity Sewer and Interceptor Upgrades. The cost of bypass pumping is an update and refinement to the *Collection System Master Plan Final Report* (*MWH, July 2007*) costs and differentiated by pipe size to account for more flow in larger pipe.

A per foot cost associated with reconnection of service laterals along the upgraded segment was also included. A cost allowance of $1,200 is provided for each service reconnection. Two services are assumed for each 100 feet of upgraded pipe. A unit reconnection cost of $24.00 per foot was included in the project unit cost for Trenched Gravity Sewer and Interceptor Upgrades .

Trenched Inline Storage

Project unit costs for Trenched Inline Storage were developed with cost as function of size (depth x width box culvert) using Approach 1. Trenched Inline Storage project unit cost tables appear in Appendix 4A.

Project unit costs for this category of work are applicable to inline storage facilities immediately adjacent to existing sewer alignments. These facilities provide peak wet weather flow attenuation to address hydraulic deficiencies in existing gravity sewers.

Project unit cost evaluations include epoxy lined concrete box culvert with grouted flow channel placed after backfill. Unit costs include a transition structure at each end of the storage segment, access hatches 100-foot on center, and water service extension for wash down. Open cut trenching is assumed for all inline storage facilities.

Cost allowances for bypass pumping and reconnection of existing services include the following:

- A component unit cost of $17.00 per foot for bypass pumping on existing pipes 24-inches and smaller.
- A component unit cost of $21.00 per foot for bypass pumping on existing pipes larger than 24-inches.
- A component unit cost of $24.00 per foot for reconnection of existing services.

Trenched Siphon Structures

Project unit costs for Trenched Siphon Structures were developed with cost as function of largest pipe diameter using Approach 1. Project unit costs for this category of projects are applicable to construction of siphon pipes used to eliminate the need for significant lengths of deep sewer downstream. This project category may also be used to replace existing siphons where hydraulic or condition deficiencies have been identified. Canal crossings are typical sites for application of Trenched Siphon Structures.

This category is applicable to double barrel siphon with structures at the terminal ends to provide access for connections to new and existing sewers, and for inspection and maintenance. Project unit costs are based on pipe embedded in concrete for siphon. Open cut trenching is assumed for all new siphon pipe installation. In the case of installation under a canal, construction is assumed to occur during the non-irrigation season.

Trenched Force Mains

Project unit costs for Trenched Force Mains were developed with cost as a function of pipe diameter using Approach 3. This category of project is applicable to new force main pipe installed in new open cut trenches or upgrade of existing force mains in existing trenches. This category of work is used to upsize a force main to address hydraulic deficiencies or replace a force main in kind to address condition deficiencies.

Project unit cost development was based on PVC pipe materials for force mains. Air release and vacuum assemblies/clean-outs are included in the project unit cost. Open cut trenching is assumed for all new and replacement force mains considered in the optimization process and advancement to the CIP list unless identified specifically as a project using trenchless technology. Odor control is not included in this unit cost. Project unit costs include no bypass pumping operations and no allowance for connection or reconnection of pressure services to individual residential or commercial customers is included. Project unit costs for new and replacement (upgraded) force mains are assumed equal in the optimization model and CIP list.

Trenchless River/Railroad/Highway Crossing Force Mains

Project unit costs for Trenchless River/Railroad/Highway Crossing Force Mains were developed with cost as a function of pipe diameter using Approach 1. This category of work is applicable to new force mains installed by trenchless means and target locations for this installation method are river, railroad or highway crossings where open cut methods are not practical or permissible. Trenchless force mains were evaluated in the optimization process and CIP list only where trenchless construction was considered applicable to address specific site conditions.

Project unit costs development was based on directional drilling using HDPE pressure pipe materials installed directly in a new bore. Cost allowances provide for excavation and restoration of bore pits at each end of the crossing segment, support and protection of utilities in the work area, and coordination with utilities. Surface restoration along the force main route is not a typical consideration for directional drilling work and no cost allowance is provided. Project unit costs were developed assuming no bypass pumping or reconnection of services.

Trenchless Canal/Railroad/Highway Crossing Gravity Sewers

Project unit costs for Trenchless Canal/Railroad/Highway Crossing Gravity Sewer were developed with cost as a function of pipe diameter using Approach 1. Project unit costs for this category of work are applicable to new gravity sewers and interceptors installed by trenchless means. Tunneling (bore and case) construction was evaluated in the optimization process and CIP list on a case-by-case basis where trenched gravity sewer crossings were not considered applicable due to specific site conditions. Target locations for this category of work are canal, railroad, or highway crossings where open cut methods are not practical or permissible.

Project unit costs are based on gravity pipe materials installed in a steel casing inserted directly in a new bored hole. Cost allowances provide for excavation and restoration of bore pits at each end of the crossing segment, support and protection of utilities in the work area, and coordination with utilities. Project unit costs include manholes at the terminal ends of Trenchless Canal/Railroad/Highway Crossings Gravity Sewers to provide access to connection with new and existing facilities. Surface restoration along the alignment is not a typical consideration in bore and case construction and no cost allowance is provided. Project unit cost development assumed no bypass pumping or reconnection of services.

Trenchless Gravity Sewer Upgrades

Project unit costs for Trenchless Gravity Sewer Upgrades were developed with cost as function of pipe diameter less than 24 inches in diameter and depth less than 20 feet using Approach 2. Project unit costs for this category of work are applicable to upgrade of existing gravity sewers to address hydraulic or condition deficiencies where open-cut trenching was expected to be too disruptive or inconsistent for open-cut work. Pipe bursting or pipe reaming were evaluated in the optimization process and CIP list only for upgrade of hydraulic or condition deficient gravity sewer pipe on case-by-case basis.

Pipe bursting or pipe reaming methods typically incur overall project costs greater than the discrete cost of pipe rehabilitation alone and incidental work can be significant component of these types of projects. Because manholes and laterals are usually in similar condition to the mainline, manholes and laterals are often replaced during trenchless gravity sewer upgrades. Significant incidental costs associated with their replacement has been included. Project unit cost development also provides allowance for potholing and protection of utilities, correction of mainline sags, and surface restoration. Project unit cost includes entry and receiving pits, surface restoration at pits, open cut lateral connections, and surface restoration along the alignment. Potholing, support and protection of utilities in the work area, and coordination with utilities are expected. To account for these incidentals, the component unit cost includes $24 per foot for incidental construction and was developed from representative projects bids using Approach 2. The 30% Construction Contingency is not included in this estimate because it is accounted for in different allowances.

Project unit costs allowances for bypass pumping and reconnection of service laterals are included in the cost of pipe segments upgraded using trenchless technology.

- A component unit cost of $17.00 per foot for bypass pumping on existing pipes 24-inches in diameter and smaller
- A component unit cost of $21.00 per foot for bypass pumping on existing pipes larger than 24-inches in diameter
- A component unit cost of $24.00 per foot for reconnection of existing services

Trenchless Gravity Sewer Rehabilitation

Project unit costs for Trenchless Gravity Sewer Rehabilitation were developed with cost as function of existing pipe diameter using Approach 2. Project unit costs applicable to this category of work are for rehabilitating existing gravity sewers to address condition deficiencies where open-cut trenching was expected to be too disruptive or inconsistent with costs for open-cut work. Cured-in-place Pipe (CIPP) was evaluated in the optimization process and CIP list only for rehabilitation of condition deficient gravity sewer pipe on a case-by-case basis.

Project unit cost development was based on CIPP techniques using epoxy impregnated felt liner pipe. Alternative techniques are potentially feasible on a case-by-case basis.

Project unit costs assume entry and receiving pits will not be required for rehabilitation using CIPP. Trenchless gravity sewer rehabilitation projects often have overall costs that are significantly higher than the mainline alone and incidental work can be a significant component of these types of projects. Manholes and laterals are often replaced because they are in as poor a condition as the mainline. Additionally, a significant amount of mainline sag repair, utility coordination, surface restoration, and curb and sidewalk work is undertaken with these projects. To account for these incidentals, a cost of $20 per foot for project incidental for trenchless rehabilitation was added. The incidental cost was developed from representative projects bids using Approach 2.

Project unit costs for Trenchless Gravity Rehabilitation include bypass pumping for each segment of rehabilitated pipe;

- A component unit cost of $17.00 per foot for bypass pumping on existing pipes 24-inches in diameter and smaller
- A component unit cost of $21.00 per foot for bypass pumping on existing pipes larger than 24-inches in diameter

Project unit costs include allowances for service reconnection and surface restoration. Two services are assumed for each 100 feet upgraded pipe. Some CIPP work may benefit from use of internal robotic lateral reconnection resulting in a lower reconnection cost as compared to open cut gravity sewer reconnection. A component unit cost of reconnection of $20.00 per foot is included.

NON-LINEAR ASSET PROJECTS

Non-Linear Asset Project Unit Costs Assumptions

The following costs assumptions, where applicable, have been included in the development of project unit costs for non-linear assets. Component unit costs for non-linear assets were developed using Approach 2.

Land Acquisition

A component unit cost of $350,000 per acre was used for the cost of land acquisition associated with non-linear assets. Cost of land acquisition was based on a web-based query of true market value for ten parcels of land within the City Urban Growth Boundary. Reference parcels were selected at random from sites in general proximity to non-linear assets identified as potential solutions to hydraulic deficiencies. Real market value data references 2012 Deschutes County Assessor's Office data YR2012. Cost of land acquisition at $350,000 per acre assumes purchase cost only. The cost of administrative and legal resources required to procure property is assumed to be covered by the Owners administrative and legal mark-up associated with the development of the over-all project cost.

Land acquisition costs were added to the reference cost data to formulate construction unit costs. Construction unit costs were multiplied by mark-up for engineering and administration to generate project unit cost curves.

Access, Security, Landscape

Access, Security and Landscape costs are included in the reference cost data used to formulate project unit cost curves.

Utility Services

Costs for water, sewer, gas and communication utility service are included in the reference cost data used to formulate project unit cost curves.

The cost of substantial upgrade or extension of primary power service (and other utilities) required for planned projects was assumed to be carried by the utility provider with provisions for cost recapture through user fees.

Non-linear Asset Project Unit Costs

New Lift Stations

Project unit cost estimates are based on two incremental sizes of new lift stations evaluated as part of the collection system optimization process; area lift stations less than 1,450 gpm rated capacity, and regional lift stations greater than 1,450 gpm Rated Capacity. The rated capacity is the pumping capacity with the largest pump out of service and must pass peak wet weather flow.

New Area Lift Stations (< 1,450 gpm Rated Capacity)

Project unit costs for this category of work are applicable to replacement of an existing lift station to address hydraulic deficiencies, a new area lift station replacing multiple lift stations, or a new area lift station in a new service area.

Development of project unit cost curves was based on open cut excavation, cast-in-place concrete wet well construction and submersible pumping equipment.

Unit cost includes exterior mounted electrical and control equipment in weatherproof enclosures, and a standby generator provides back-up power. Installations include liquid level monitoring, pressure monitoring, flow monitoring, bypass pumping port and telemetry equipment. Vapor phase odor control at the wet well and liquid phase odor control equipment is included. The footprint of the station, including wet well and control building, is assumed to be 800 square feet. A buffer zone of 50 feet is included in area requirements. Required lift station land area is assumed to be 0.14 acres.

Project unit costs curves for new area lift stations less than 1,450 gpm capacity were developed with cost as function of peak wet weather flow and total dynamic head at peak wet weather flow. Using Approach 2, construction unit costs referencing the cost of similar projects were increased by the cost of land acquisition and then multiplied by mark-up for engineering and administration to generate project unit costs. If component unit costs for required components (e.g. odor control) was not in the similar projects, these component costs were added to create consistent projects for cost comparison. Project unit costs curves appear in Appendix 4A.

New Regional Lift Stations (>1,450 gpm Rated Capacity)

Project unit costs for this category of work are applicable to replacement of an existing regional lift station to address hydraulic deficiencies, a new regional lift station replacing multiple area lift stations, or a new regional lift station in a new service area.

Development of project unit cost curves was based on open cut excavation, cast-in-place concrete wet well construction and submersible pumping equipment.

Project unit cost includes electrical and control equipment housed in a control building, and a standby generator provides back-up power. Installations include liquid level monitoring, pressure monitoring, flow monitoring, bypass pumping port and telemetry equipment. Vapor phase odor control at the wet well and liquid phase odor control equipment are included. The footprint of the station, including wet well and control building, is assumed to be 1,200 square feet. A buffer zone of 70 feet is included in area requirements. Required lift station land area is assumed to be 0.25 acres.

Project unit cost curves for new regional lift stations greater than 1,450 gpm capacity were developed with cost as function of peak wet weather flow and total dynamic head at peak wet weather flow. Using Approach 2, construction unit costs referencing the cost of similar projects were increased by the cost of land acquisition and then multiplied by mark-up for engineering and administration to generate project unit costs. If component unit costs for required components (e.g. odor control) was not in the similar projects, these component costs were added to create consistent projects for cost comparison. Project unit cost curves appear in Appendix 4A.

Decommission Lift Stations

Project unit costs for the decommissioning of area lift stations includes the lump sum to demolish and remove the lift station and all appurtenances. This project unit cost will be used if a lift station is no longer needed due to connection to the gravity system. The cost of gravity connection and any other connections necessary uses other applicable project unit costs. Project unit costs were developed using Approach 3.

Existing Lift Station Upgrades (Area Lift Stations)

Project unit costs for this category of work are applicable to replacement of the wet well and pump equipment at existing area lift stations to address condition deficiencies or minor hydraulic deficiencies. In the optimization model and CIP list, lift station upgrades do not include force main replacement. The cost of any force main replacement utilizes the trenched force main project unit cost.

Project unit cost for Existing Lift Station Upgrades includes open cut excavation and installation of a new prefabricated wet well and submersible pumping equipment. New electrical and control equipment is exterior mounted in weatherproof enclosures. Standby power is provided by means of a portable generator. Installations include liquid level monitoring, pressure monitoring, flow monitoring, bypass pumping port and telemetry equipment. No vapor phase odor control at the wet well or liquid phase odor control equipment is included. Upgrades are assumed to fit within the site area occupied by existing lift station facilities with no expansion of land ownership or easement required.

Using Approach 2, construction unit costs referencing the cost of similar projects were multiplied by mark-up for engineering and administration to generate project unit costs. Project unit costs for Existing Lift Station Upgrades are provided in Appendix 4A.

Off-Line Storage

Project unit costs for this category of work are applicable to off-line storage facilities constructed separately from new or existing elements of the collection system. These facilities provide wet weather flow attenuation to address hydraulic deficiencies. During normal dry weather operation, off-line storage facilities would be dry and in standby service.

Project unit cost curves for off-line storage are based on open cut excavation, cast-in-place concrete basin/tank construction and concrete masonry control building construction. Off-line storage concepts forming the basis of project unit cost curves are below grade concrete basins. Further development of off-line storage design for a specific site would be deferred until design and implementation as a CIP project.
Odor control equipment is included in the cost assumptions. A 100-foot buffer zone is included in land procurement assumptions to facilitate access, security, visual mitigation (landscaping), overflow containment, and odor mitigation. Costs include pump-back facilities to transfer stored water after the wet weather flow event.

Project unit costs also include;

- Control building
- Weir manhole junction at the conveyance system point of diversion
- Wastewater conveyance and return lines to collection system
- Mixing and/or aeration equipment sized for total basin volume
- Potable water and sanitary service connections
- Medium voltage electrical service connection
- Perimeter fencing and security system
- Gravel access drive and landscaping

Project unit cost curves for Off-Line Storage facilities were developed with cost as function of total storage capacity. Using Approach 2, the cost of constructing similar projects was increased by the cost of land acquisition and then multiplied by mark-ups for engineering, legal and administration to generate project unit costs. Project unit costs curves for Off-Line Storage projects appear in Appendix 4A.

Satellite Treatment Facilities

Project unit costs for this category of work are applicable to satellite treatment facilities constructed in lieu of new elements of the collection system. These facilities provide treatment of wastewater flow to eliminate the need for downstream conveyance or upsizing of downstream conveyance in response to hydraulic deficiencies.

Project unit costs for Satellite Treatment Facilities are based on complete wastewater treatment plants (screening and reduction of organic load/nutrients). Project unit costs include both liquid and solids treatment processes, and generally reflect systems that can provide low effluent total nitrogen (TN<10 mg/L) and/or "advanced treatment." Project unit costs used in the optimization process reflect treatment systems that generate high quality effluent assuming that facilities are responsive to stringent discharge criteria and/or reuse opportunities.

Cost curves incorporated in optimization did not include a budget allowance for procurement of land necessary to site treatment, treated water storage, treated water disposal or solids disposal facilities. Project unit costs do not include collection system improvements needed for flow diversion, or conveyance systems to and from the treatment plant. Further consideration of these requisite elements of a satellite treatment facility would be required to fully evaluate the cost/benefit of a specific project at a specific site.
Costs curves were developed from published construction cost data and cost data from similar facilities constructed in the Bend area and the Northwest. Using Approach 2, construction unit cost references were multiplied by mark-ups for engineering and administration to generate project unit costs. Cost curves appear in Appendix 4A.

OPERATION AND MAINTENANCE COST

Capital cost (initial cost) is coupled with O&M cost according to asset type and size to derive the total cost associated with constructing and operating an asset over its useful life. O&M costs for collection system piping, lift stations and treatment facilities were developed from operating cost data (2011-2012), and proposed operating budgets (2013-2014) provided by the City. The City of Bend collection system O&M budget is itemized in Table 4-3. Treatment facility O&M budget information is itemized in Table 4-4.

Table 4-3
City of Bend 2013-2014 Collection System O&M Budget

Budget Item	Sewer Lines (Gravity Sewer, Vacuum Sewer & Force Main)	Lift Stations
Labor	$1,651,470	$663,464
Material and Services	$97,959	$36,041
Electricity	$0	$150,000
Odor Control	$210,000	$0
Capital Maintenance Projects	$995,000*	$170,000*
Vehicle and Communications	$51,458	$450,710
Other	$1,548,310**	$668,153**
Total	**$4,554,197**	**$2,138,368**

** 2013-2014 Collection System O&M Budget - Capital Maintenance Projects line item revised to remove Capital Improvement Projects. Repair and maintenance budget line items retained.*

*** 2013-2014 Collection System O&M Budget – "Other" line item revised to remove debt service costs.*

Table 4-4
Projected City of Bend WRF O&M Budget

Budget Item	Water Reclamation Facility (Wastewater Treatment Plant)
Labor	$1,703,259*
Material	$236,485*
Services	$229,814*
Utilities	$333,187*
Capital Maintenance Projects	$0**
Operation Support Equipment	$301,554***
Other	$1,528,374****
Total	**$4,332,674**

** 2011-2012 WRF Budget escalated. Select 2013-2014 budget line items added.*

*** 2013-2014 WRF Budget - Capital Maintenance Projects line item revised and removed Capital Improvement Projects.*

**** 2011-2012 WRF Budget escalated. Select 2013-2104 Budget line items added. Vehicle purchase depreciated.*

***** 2011-2012 WRF Budget escalated. Select 2013-2104 Budget line items added. 2013-2014 Budget - "Other" line item revised to remove debt service costs.*

2013-2014 O&M expenditures for collection system and wastewater reclamation assets include a line item for capital maintenance projects. This line item includes budget commitments for the maintenance, rehabilitation and replacement of asset components. The portion of the budget associated with rehabilitation and replacement was removed to avoid double-counting replacement costs in both the O&M and the equivalent uniform annual cost components. Programs for capitalizing rehabilitation and replacement typically provide for an annual budget equal to full asset value divided by the service life of the asset. Further discussion of O&M capital maintenance budget with regard to rehabilitation and replacement are presented in the Section X - Condition Evaluation and System Replacement Costs.

Sewer Lines - Annual O&M Costs

The City of Bend collection system currently includes approximately 2,218,000 lineal feet of gravity sewer, vacuum sewer and force mains of various sizes. Because larger pipes typically require more resources and different equipment for inspection, cleaning and maintenance, the cost of operating and maintaining these pipes is higher. Referencing the 2013-2014 Collection System Budget, the annual O&M unit cost for sewer lines is shown in Table 4-5. To develop this annual O&M unit cost, the O&M budget was divided by the number of diameter inch-feet (product of sewer diameter expressed in inches times its length express in feet) of collection system piping and then distributed by pipe diameter.

Table 4-5
Gravity/Force Main Collection System - Annual O&M Unit Cost

Diameter (inches)	O&M Cost ($/ft)
2	$0.48
2.5	$0.60
3	$0.73
4	$0.97
6	$1.45
8	$1.94
10	$2.42
12	$2.90
15	$3.63
16	$3.87

Diameter (inches)	O&M Cost ($/ft)
18	$4.36
20	$4.84
21	$5.08
24	$5.81
27	$6.53
30	$7.26
36	$8.71
42	$10.16
48	$11.61
54	$13.07

Diameter (inches)	O&M Cost ($/ft)
60	$14.52
66	$15.97
72	$17.42
78	$18.87
84	$20.32
90	$21.78
96	$23.23
102	$24.68
108	$26.13

Lift Stations - Annual O&M Costs

The collection system includes 87 lift stations (area lift stations plus regional lift stations) having a combined total of 2,323 horsepower. These figures do not include the 248 residential lift station/pumping systems also maintained by the City.

Referencing 2013-2014 budget data for lift station O&M, minus the electrical power costs, the annual O&M cost for area and regional lift stations, is $856 per horsepower of total lift station capacity. Assigning O&M costs proportional to total horsepower reflects the increased maintenance that typically occurs at larger lift stations as compared to smaller lift stations. Larger lift stations have more equipment (variable frequency drives, odor control, HVAC, SCADA, etc.) to maintain and typically require more O&M attention.

Referencing 2013-2014 budget data for lift station O&M, the current average annual electrical cost incurred at area and regional lift stations is $65 per horsepower of total lift station capacity. Assigning electrical costs proportional to total horsepower reflects the increased energy costs associated with larger lift stations as compared to smaller lift stations.

Current Energy Costs

Evaluation of lift station alternatives includes anticipated energy consumption and associated energy costs over time. These costs are used in the optimization model and account for increasing flow rate, energy use and energy costs over time.

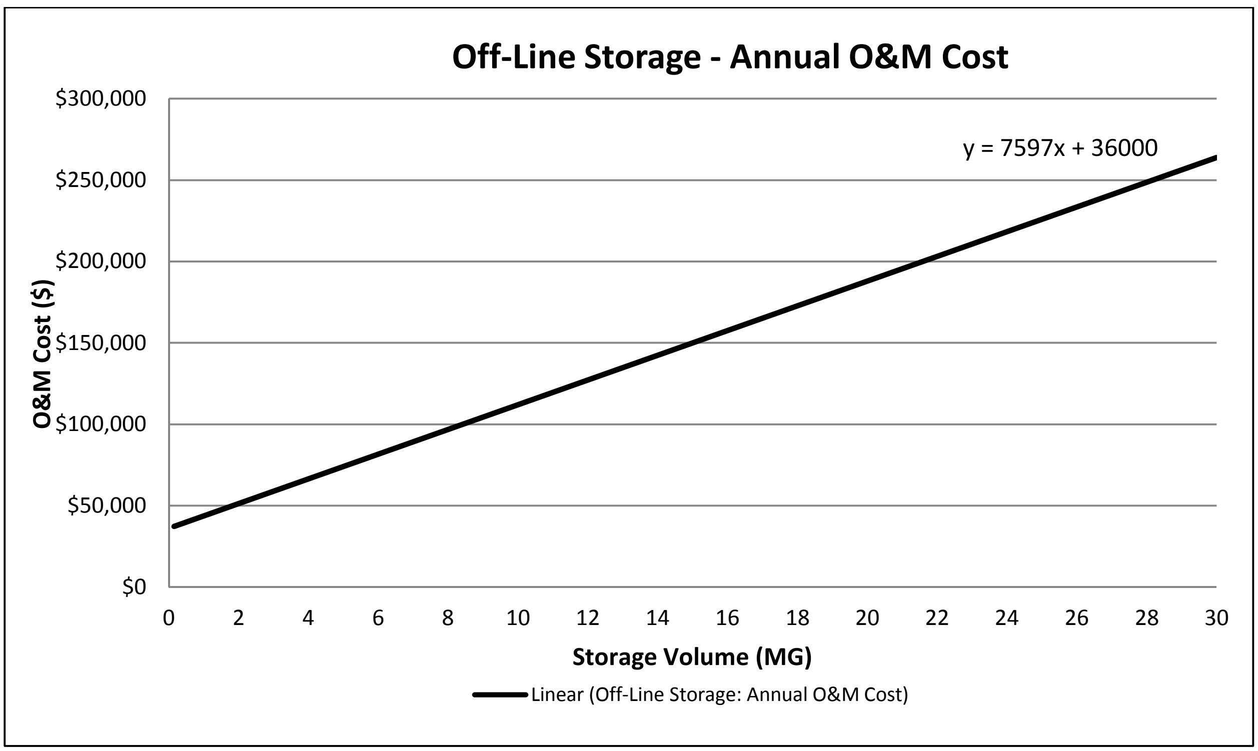
The cost of electrical energy at City of Bend lift stations is the cumulative total of basic charges, demand charges, other fees, taxes, etc. Using power bills from two representative lift stations in the City system, the current cost of electrical power at a typical lift station is approximated at $0.185/kW/hr.

Off-line Storage - Annual O&M Costs

Annual O&M costs were developed from an estimate of labor, utilities and materials required to operate facilities. An annual O&M cost curve was developed with cost as a function of storage capacity expressed in million gallons.

ANNUAL O&M COST($) = (7,597)(Storage Volume MG) + 36,000

Figure 4-1
Off-Line Storage - Annual O&M Cost



Satellite Treatment Facilities - Annual O&M Costs

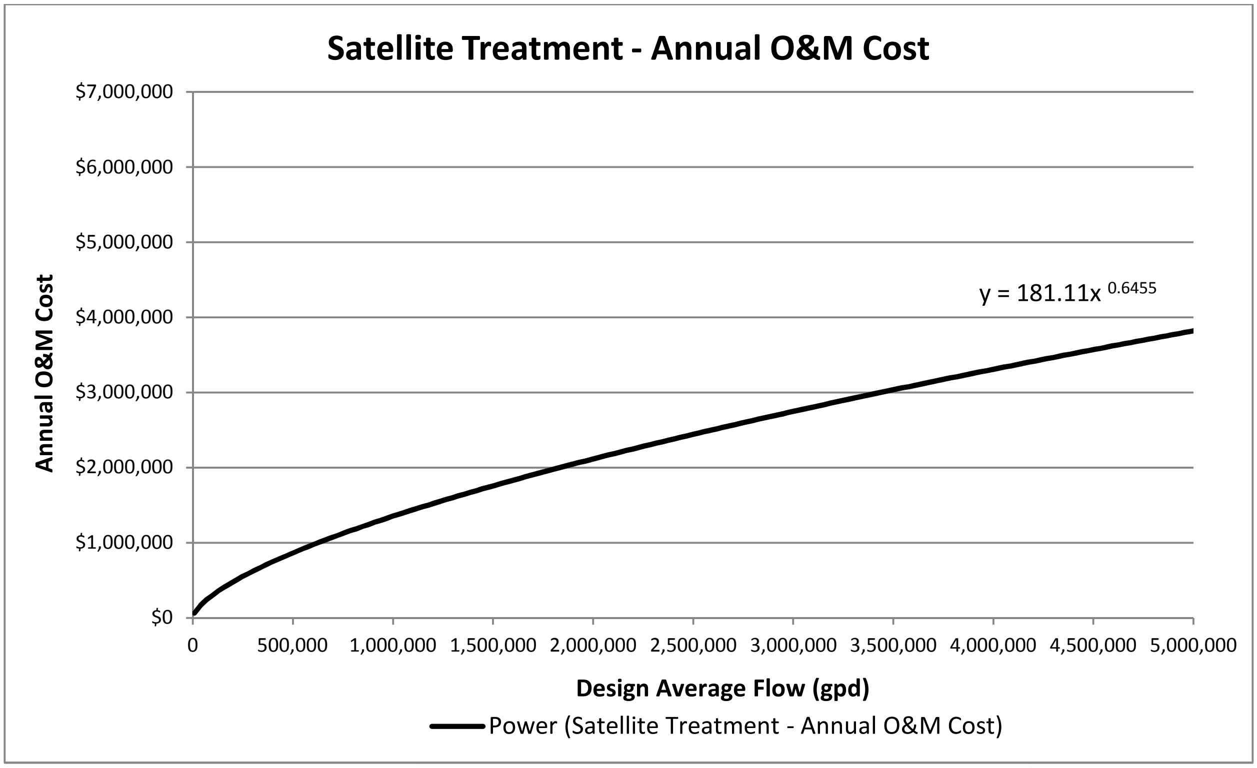
Annual O&M cost curves were developed from published data, vendor provided information meeting the project viability criteria, MSA project work, City provided O&M cost and budget data, and O&M cost data provided by two other Northwest municipalities. Source data was adjusted, as necessary, to develop a cost curve that agrees with the WRF O&M data provided by the City and establish a uniform basis for comparison. Treatment facility operation and maintenance cost data used in cost curve development includes:

- Direct Labor (burdened salary/rate)
- Utilities (electricity, gas, etc.)
- Materials (spare parts, chemicals, polymers, etc.)
- Services (lab testing, consulting, janitorial, etc.)
- Support Equipment (tools, phones, computer systems, maintenance equipment, etc.)
- Shared City Costs (Administrative, billing, facilities, etc.)
- Solids Disposal, if not covered elsewhere.

An annual O&M cost curve was developed with cost as a function of average design flow expressed in gallons per day.

$$\text{ANNUAL O\&M COST(\$)} = (181.11)(\text{FLOW}_{\text{DESIGN AVERAGE}})^{0.6455}$$

Figure 4-2
Satellite - Annual O&M Cost



COST ANALYSIS

Equivalent Uniform Annual Cost (EUAC) was used for economic comparison of alternatives in the collection system optimization process. EUAC is the cost of owning, constructing, operating and maintaining the collection system components converted to the uniform per year basis. EUAC analysis provides a long-term assessment of project effectiveness as compared to evaluating up-front capital cost (initial cost) alone. EUAC includes consideration of;

- Capital Cost (Initial Cost) including land procurement, engineering, administration, and construction
- Operation and Maintenance Cost including electrical costs
- Opportunity Cost of Capital
- End-of Life Replacement Cost

Initial Cost

Initial cost of a collection system asset is derived from the project unit costs discussed previously. Project unit cost tables and project cost curves are presented in Appendix 4A.

Useful Life

Cost analysis conducted within the optimization model incorporates the useful life of an asset to calculate the present value of constructing and maintaining an asset over its useful life. The useful life of a collection system and treatment system asset will vary depending on the environment of service, materials of construction, service duty and maintenance.

Useful life values have been published by the Environmental Protection Agency (EPA, 2002) and the American Society of Civil Engineers (ASCE, 2011) and used as the basis for defining useful life for EUAC analysis. Useful life values used in EUAC analysis are provided in Table 4-6.

Table 4-6
Collection and Treatment System Asset Useful Life

Asset	Lifespan (years)
Gravity Sewers and Interceptors including Trenchless Canal/Railroad/Highway Crossing Gravity Sewers	80
Manholes	80
Inline Storage Pipes	50
Force Mains and Trenched Siphon Structures	50
Concrete Structures associated with Lift Stations, Off-line Storage, and Satellite Treatment Facilities	50
Above Ground Pipe, Fittings, and Valves associated with Lift Stations, Off-line Storage, and Satellite Treatment Facilities	50
Pumps, HVAC, other Mechanical Equipment	20
Electrical Equipment	20
Controls and Instrumentation	20
Satellite Wastewater Treatment Facility	*40* *
New Lift Stations and Existing Lift Station Upgrades	*35* **

* *Developed from cost weighted average on typical WWTP component make-up (concrete structures, mechanical equipment, etc.)*
** *Developed from cost weighted average on typical lift station component make-up (concrete structures, mechanical equipment, etc.)*

Analysis Period

EUAC is an annualized measure that is independent from the analysis period. On a real (uninflated) basis, EUAC is valid for any number of asset life cycles.

Future Costs

EUAC is based on current (2013) unit costs. To translate EUAC to a future cash flow, an inflationary adjustment must be applied.

Future Cost of Capital Expenditures

Analysis of the (20-city) CCI published by the Engineering News Record identified the 23-year arithmetic mean of escalation of capital projects at 3.1% per year.

Future Cost of O&M

O&M costs increase over time and projections of future O&M costs are developed using an escalation rate. Escalation rate for operating expenses is best reflected by the Consumer Price Index for all urban consumers (CPI-U). This index is the most widely accepted measure of general inflation. Using a 23-year arithmetic mean, estimated future increases in this index is 2.6% per year.

Future Costs of Energy

In 2013, the NW Power and Conservation Council published a 20-year forecast (through 2032) of Mid-Columbia wholesale power prices as a mid-term revision of its 6th Northwest Power Plan. Referencing this source, cited in recent work conducted by the City with regard to the proposed City of Bend Surface Water Improvement Project, the cost of power is projected to increase at an average rate of 5.3% per annum through 2032.[2]

Additional analysis was conducted on electrical prices for both consumers and producers using data from the Bureau of Labor Statistics. Based on research conducted and coordination with City of Bend Finance Department, an Escalation Rate of 3.9% was selected for electricity expenses associated with the collection system assets.

Nominal Discount Rate

Nominal Discount Rate reflects the opportunity cost of capital for sewer collection system projects in Bend. Based on coordination with City of Bend Financial Department, a Nominal Discount Rate of 4.9% has been selected for economic analysis of alternatives.

Real Discount Rate

Real Discount Rate is developed using escalation rates to deflate the nominal discount rate. The optimization cost model uses the real discount rate for capital to calculate EUAC. Based on research conducted and coordination with City of Bend Financial Department, a real discount rate of 1.7% for capital expenditures was used for economic analysis of alternatives.

[2] Sixth Power Plan Mid-term Assessment Report, Northwest Power and Conservation Council, March 13, 2013.

Table 4-7 lists the real discount rate for capital as used in the optimization model. Table 4-7 also lists real discount rates for O&M and electricity as a comparison.

Table 4-7
Real Discount Rate

Category	Annual Rate
Capital	1.7%
Operations and Maintenance	2.2%
Electricity	1.0%

EUAC Evaluation of Alternatives

The optimization process utilizes all relevant EUAC's including capital costs, operations and maintenance costs, and end-of-life replacement costs to evaluate improvements alternatives. The individual EUAC components (capital, O&M, etc.) are combined to produce a total EUAC cost for each improvement alternative under consideration. An alternative with a lower EUAC is the preferred alternative.

When comparing the cost of an existing pump station and force main system against the cost of a new gravity sewer that would allow the pump facility to be decommissioned, the costs of an existing pump facility are treated as though the pump facility is a new asset. This modeling approach assumes that implementation of the gravity alternative roughly coincides with end-of-life replacement of the existing pump facility.

Costs that are not affected by improvement alternatives (e.g., O&M costs for existing lift station that will not be affected by alternatives) will not be included in the optimization and are referred to as "base-costs." Base costs for a solution set are quantified independently of the optimization analysis, but are included in the solution set summary.

Projects Starting at the Same Time

The optimization process compares the EUAC of collection system alternatives assuming that all alternatives are realized at the same time. The present value of the cost of one lifecycle of each asset is calculated. The present value is then converted to an EUAC and the EUAC's compared to identify the least cost alternative.

Present Value - The annual incremental cash flows for a project, whether capital or operational, are discounted to present value. Both the cash flows and discount rate are real rather than nominal values. Discount rates reflect the risk of the project and current conditions in the capital market. Real discount rates in the range of 1.7% to 2.2% are applicable to the projects being considered.

EUAC - This is a calculation of the amount of money that, if spent annually over the useful life of the constructed asset, would have the same present value as the present value of the project. This measure allows comparison of competing projects with different useful lives.