DELGANY INTERCEPTOR AND SOUTH PLATTE RIVER STUDY

ALTERNATIVES ANALYSIS

Prepared for

City and County of Denver
Department of Public Works

June 28, 2017

6200 South Quebec Street
Greenwood Village, CO 80111

Project 60531189

AECOM

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List of Abbreviations

AACEI	Association for the Advancement of Cost Engineering International
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BOD	5-day Biochemical Oxygen Demand
BOE	Basis of Estimate
CAC	National Western Center Citizens Advisory Committee
COD	Chemical Oxygen Demand
COP	Coefficient of Performance
CSU	Colorado State University
DHEW	District Heat Energy from Wastewater
DI	Delgany Interceptor
EER	Embrace an Ethic of Regeneration
ETF	Energy Transfer Facility
EUI	Energy End-Use Intensity
gpm	gallons per minute
HEX	Heat Exchanger
mg/L	Milligrams per Liter
MW	Megawatt
MWRD	Metro Wastewater Reclamation District
NOx	Nitrous oxides
NWC	National Western Center
NWCO	Office of the National Western Center
NWD	National Western Drive
RTA	Regional Tourism Act
ROS	Riverfront Open Space
SHR	Sewer Heat Recovery
SPR	South Platte River
UDFCD	Urban Drainage and Flood Control District
USACE	US Army Corps of Engineers
VOC	Volatile Organic Carbon
WWTF	Wastewater Treatment Facility

EXECUTIVE SUMMARY

Background

The National Western Center (NWC) in north Denver will be approximately 250 acres at full buildout and represents the expansion and redevelopment of Denver's National Western Stock Show campus into a year round center for entertainment, research, education and agribusiness. The location of the NWC, along the Interstate 70 corridor and midway between Union Station and Denver International Airport, makes the NWC an attractive urban investment opportunity. The area of study for this work is the land along the South Platte River that will eventually be redeveloped as Riverfront Open Space, and contains the above-ground Delgany Interceptor pipes, twin 72" and 78" wastewater pipes that convey sewage to the Robert W. Hite Wastewater Treatment Facility 1.5 miles north of the NWC.

The Denver City Council adopted a National Western Center Master Plan in March 2015. The Master Plan was created by a collaboration of the City and County of Denver, Colorado State University, the Western Stock Show Association, History Colorado, and Denver Museum of Nature and Science. Partial funding for Phases 1-2 of the Master Plan was approved by Denver voters in November 2015 (Ballot Initiative 2C), and the State's approval of Regional Tourism Act (RTA) funds for the NWC later that same month. The NWC Master Plan defines nine Guiding Principles including the directive to "Engage the River and Nature" as the campus is redeveloped. The Master Plan recommends:

- Bury or move the Delgany Interceptor
- Create campus-wide connections to the river
- Improve river habitat and health
- Create recreational trails and education areas along the river
- Treat storm water onsite
- Aspire to create net zero or net positive impact on water quality/quantity

Purpose

The purpose of this Study is to address the NWC Master Plan recommendation to create new publicly accessible open space, habitat improvements and regional trail linkages along the SPR as part of the NWC project. This Study satisfies its purpose by focusing on the Master Plan guiding principle of bury or move the Delgany Interceptor, with additional attention to related Master Plan guiding principles of campus-wide connections to the river, improve river habitat and health, create recreational trails and education areas along the river, and treat storm water on site. In addition, this Study addresses how the decision of whether or not to relocate the Delgany affects the potential for implementation of Sewer Heat Recovery technology. The efforts needed to satisfy the purpose include three separate but related tasks:

1. Evaluate possibilities related to "re-purposing" or re-locating the existing Delgany Interceptor pipes, as well as assessing options related to Lift Station #5.

2. Evaluate options for taking advantage of the proximity of the Delgany Interceptor within the NWC to develop a Sewer Heat Recovery system as a renewable energy source

3. Evaluate the impact of the various proposed alignments on the Partners' ability to achieve the goals for the Riverfront Open Space identified in the Master Plan. Develop concepts to "Engage the River and Nature" by improving the NWC connectivity to the Riverfront and incorporate the alternatives for re-purposing or re-locating the Delgany Interceptor.

The approximately one mile long stretch of the South Platte River (SPR) adjacent to the NWC is virtually inaccessible due in part to the above ground location of the Delgany Interceptor. The Interceptor includes dual, parallel Metro Wastewater Reclamation District (MWRD) sanitary pipelines with diameters of 72 inches and 78 inches. A 1900-feet long segment of the Delgany Interceptor lays on the ground along the east bank of the SPR, roughly from the MacDonald Farms property at the south end of NWC to the Denver Rock Island Railroad maintenance facility at the north end. The Delgany Interceptors were constructed aboveground to facilitate their connection to an earlier aerial South Platte River crossing that has since been removed and was replaced in the 1960's by an inverted siphon crossing of the SPR. This eliminated the need for the Delgany Interceptors to be aboveground and created the current opportunity to relocate and bury the aboveground segment of the Delgany.

The Delgany Interceptor, owned and operated by the Metro Wastewater Reclamation District (MWRD) is a major factor in all three of the tasks performed for this Study, and all three of these tasks contribute to guiding principles of the Master Plan and enable the decisions required for implementation of Phase 1 of the Master Plan.

Delgany Alignment Analyses

The Delgany Interceptor is a critical infrastructure feature that must be addressed in the redevelopment of the National Western Center. The decision of whether to leave the Delgany in place and develop around it, or replace the Delgany Interceptor with new pipes re-located away from its current, prominent location requires consideration of many factors, including but not limited to cost, environmental impacts, accessibility, hydraulics, and impacts on other site infrastructure. Five (5) alignment options were developed in coordination with the Riverfront Open Space Alternatives. The alignments are shown on the map, Figure ES-1-1, on the following page.

Each interceptor alignment was identified as a reasonable option that satisfies the constraints and assumptions applicable to the alignments, and that provides new opportunities related to the Riverfront Open Space. The relationship between each interceptor alignment and the related Riverfront Open Space opportunities are described in Table ES-1-1.

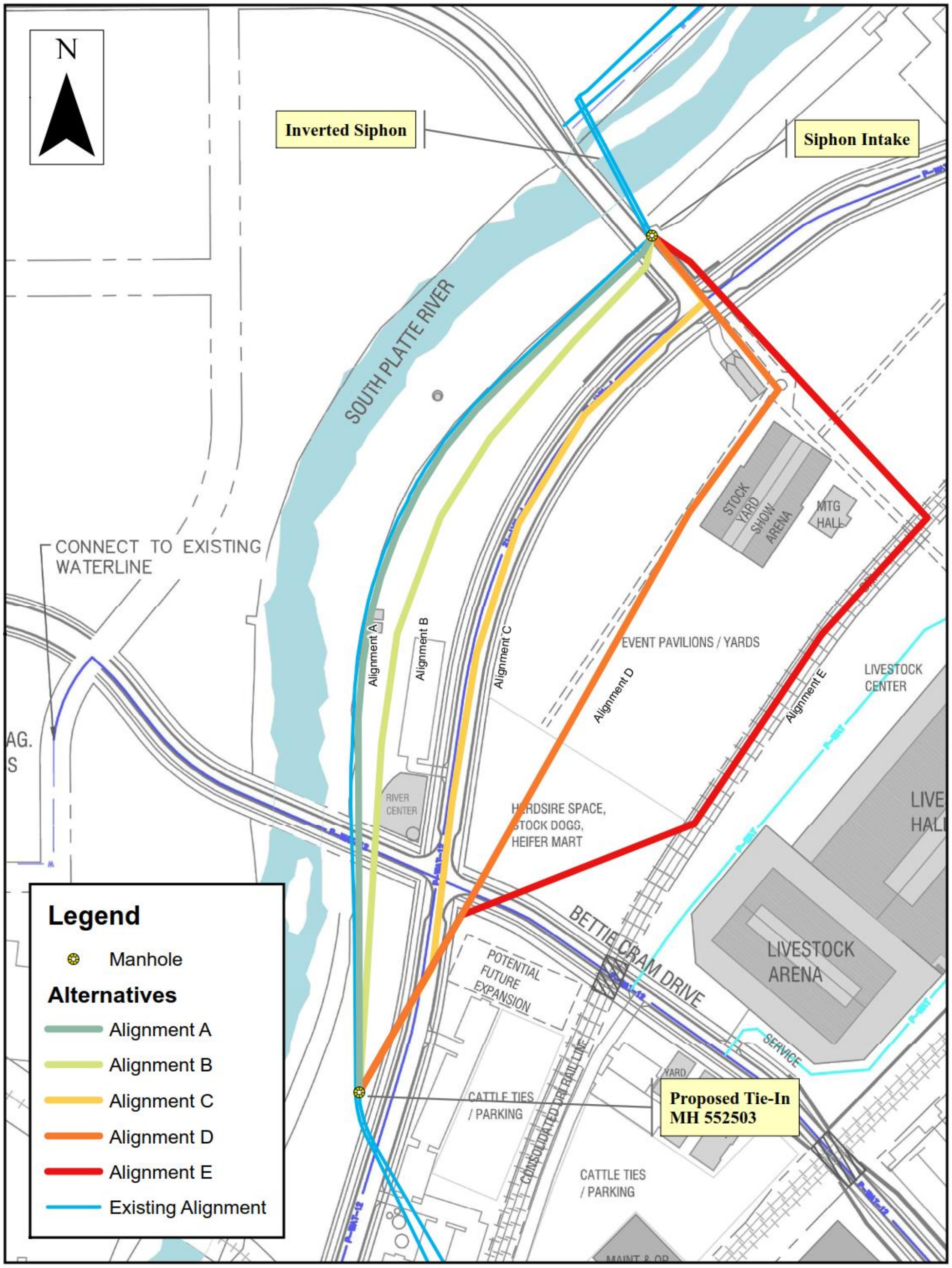


Figure ES-1-1:
Delgany Interceptor Alignments

Table ES-1-1:
Relationship Between Interceptor Alignment and Riverfront Alternative

Interceptor Alignment	Riverfront Alternative
A. *In Situ* – remains in its current location	1. Pipe remains exposed, and is bridged over
	2. Partially buried on the east side
	3. Fully buried; "bermed" over
B. Pipes moved to the east, but still within the open space	4. Fully buried within the eastern portion of the open space
C. Under National Western Drive	5. Pipes out of the open space
D. Under the Stock Yards	
E. Under or adjacent to the consolidated rail corridor	

Each of the Alignments was reviewed from a constructability perspective and to identify any possible limits the Alignment might impose on NWC development in the future. This initial review identified two alignments, Alignment D and Alignment E, that present likely conflicts with proposed NWC infrastructure and site uses. Alignments D and E were eliminated from further consideration due to their conflicts with and limits on future NWC site development. Alternatives A, B and C were retained for additional evaluation and consideration.

Engineering analyses that were performed for evaluating possible interceptor alignments involved hydraulic calculations and structural analyses. The purpose of these analyses was to confirm that the possible DI alignments would be equal to or greater than the capacities and capabilities of the existing Delgany Interceptor pipes. The results of the analyses indicate that the studied alignments are capable of meeting or exceeding the capabilities of the Delgany Interceptor.

The results of the Delgany Alignment Analyses were coordinated with the Riverfront Open Space evaluations to assess the ability of each alignment to satisfy the guiding principles of the NWC Master Plan. Development of the full potential of Riverfront Open Space at NWC, and fulfillment of many of the NWC guiding principles, can be most readily accomplished through the removal of the existing aboveground Delgany Interceptor and replacing it with new, buried interceptor pipes within the new, proposed National Western Drive (Alignment C). Refer to the Plan and Profile of Alignment C in Figure ES-2 on the following page. **The relocation of Delgany Interceptor to Alignment C provides the broadest range of opportunities for implementing Riverfront Open Space improvements, with only minimal disadvantages.** Other alignment options, including relocation of the Delgany Interceptor to an alignment across Open Space (Alignment B) could also fulfill the guiding principles, but they have other, more significant disadvantages and limitations on fulfilling all of the Master Plan guidelines.

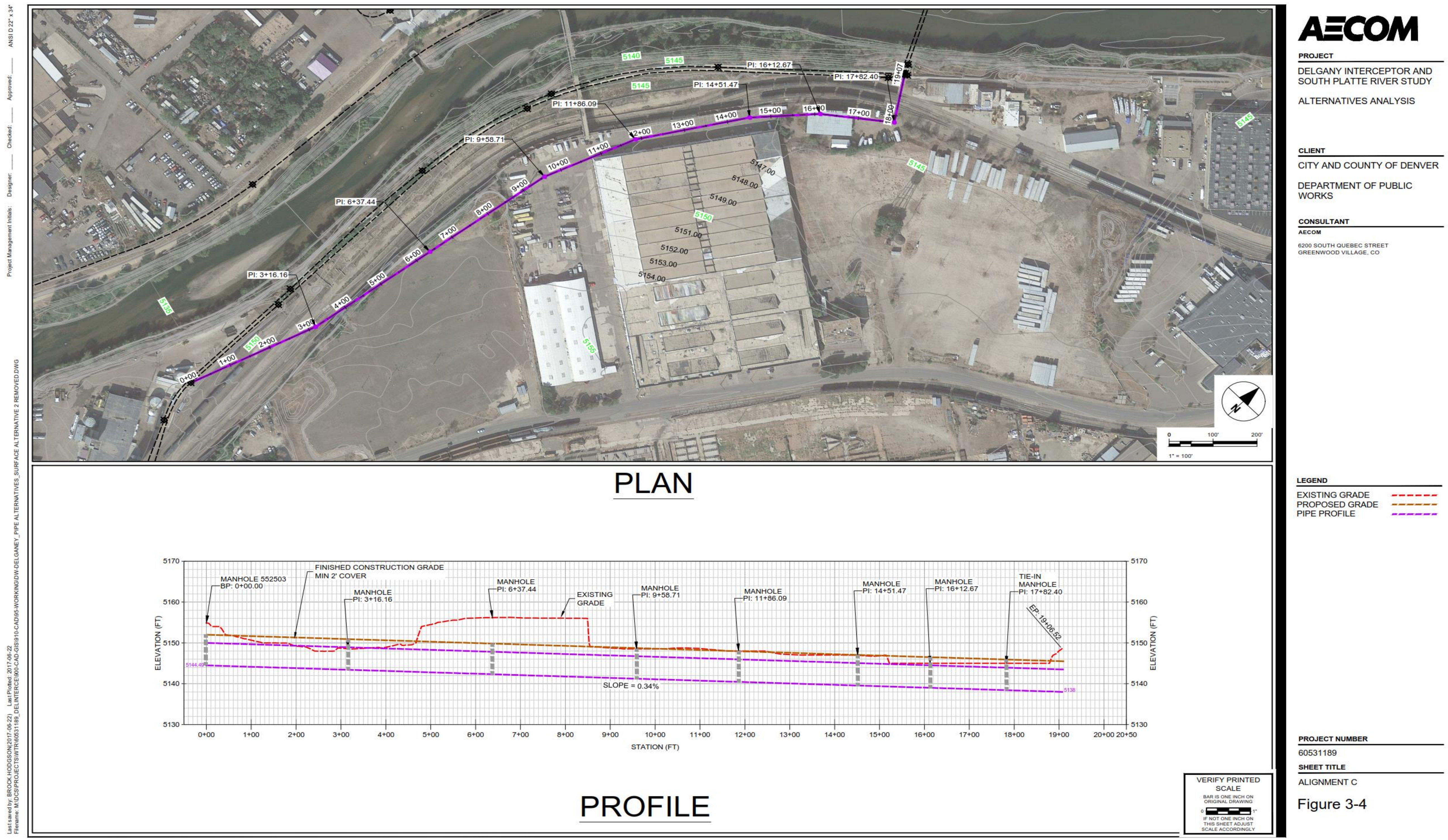


Figure ES-1-2:
Alignment C Plan and Profile

Sewer Heat Recovery (SHR) Screening

Based on the analysis of thermal energy available in the Delgany interceptor, there is an opportunity to make use of the Delgany interceptor for heating and cooling at the NWC. There appears to be sufficient thermal energy supply to operate a SHR system with heat pumps to meet the heating demands for the buildings contemplated at the NWC. Similarly, there is capacity in the Delgany interceptor to provide cooling in a district system for the NWC, with waste heat being rejected back in to the Delgany interceptor in the summer time.

To meet the thermal energy demands at the NWC, the campus would require the use of a district energy system using heat pumps and a distribution loop to provide heating and cooling for individual buildings within the NWC. Examples of SHR systems indicate that SHR systems can be cost-effective and have the potential to reduce the electricity and natural gas used to provide domestic hot water heating and space heating in the buildings, while at the same time reducing the sewage temperature in the Delgany interceptor.

If the NWC is contemplating the use of innovative technologies, it is recommended that further analysis and design development be undertaken to evaluate and refine the sizing of the SHR system in combination with thermal storage. The annual and peak heating and cooling demands for individual buildings should also be refined and confirmed at the design stage.

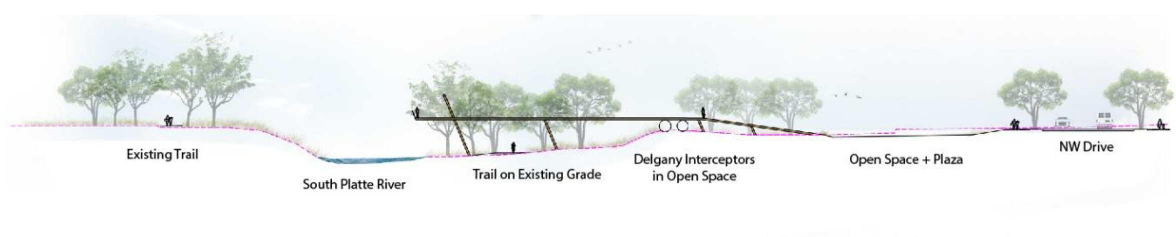
Screening criteria have been developed to assist in the evaluation of the potential for SHR and it is recommended that the screening analysis be conducted for each of the identified scenarios to confirm the scope and feasibility of SHR at the NWC.

Riverfront Open Space Evaluations

The purpose of the Riverfront Alternatives evaluations is to understand the impact of either the Delgany Interceptor (DI) remaining in place (the in situ alternatives) or relocating the pipes elsewhere within the NWC campus on the Partners' ability to create open space along the South Platte River within the NWC campus that meets the goals and intentions of the NWC Master Plan. Five Riverfront Alternatives were identified and studied- three "In Situ" alternatives where the DI pipes were left in place, and two others which investigated relocating the pipes.

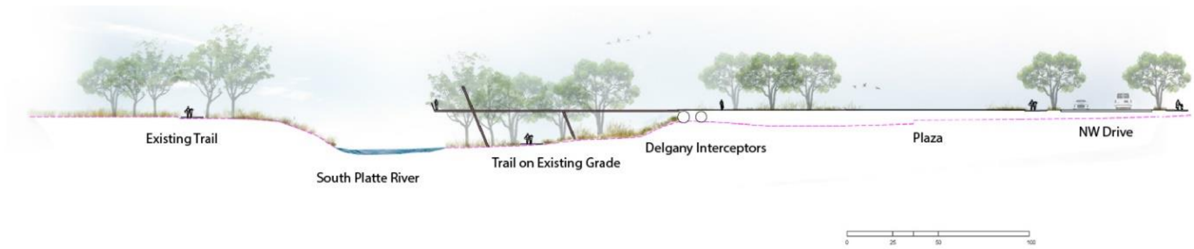
Riverfront Alternative 1: In Situ, Pipes Remain Exposed

This Alternative assumes Interceptor Alignment A is selected, and the DI pipes remain in place. No earthwork or berming on either the river side or east of the pipes is included. Ramps and stairs would be needed to allow pedestrians up and over the DI to gain access to the South Platte River. The pedestrian barrier the DI presents would remain in place; raised walks, while costly, would help break down this separation between NWC and river.



Riverfront Alternative 2: In Situ, Berm Up To Pipes on East Side

As with Alternative 1, the DI remains in place. To better accommodate pedestrian access to views of the river, earthwork/fill is added to bring the grade east of the pipes level with the tops of the pipes, allowing free movement from the Riverfront Open Space to the pedestrian boardwalk along the top of the pipe. To reach the river, stairs and ramps will be needed on the west side of the DI. Pink line indicates existing grades.



Riverfront Alternative 3: In Situ, Berm Up and Over the Pipes

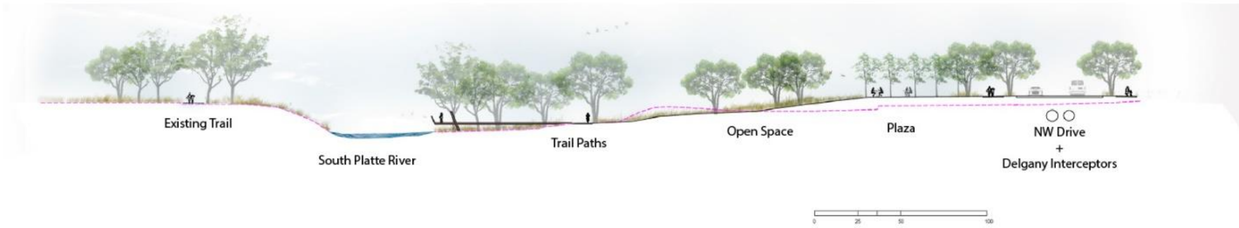
As with Alternatives 1 and 2, the DI remains in place. This Alternative explores the concept outlined in the Master Plan to cover over the existing pipes with dirt. Due to grading and minimum slope requirements, the berm would enter the river channel and negatively impact the 100-year floodplain, rending this Alternative inviable. No further study of this Alternative was completed.

Riverfront Alternative 4: DI Pipes Move Into Open Space, Adjacent to NWD

The existing DI would be removed, and a new facility relocated to Alignment B, buried within the open space between the river and National Western Drive. This would allow the banks along the river to be laid back to the east, creating a more gracious relationship of river to the NWC. The buried pipes would require an easement, which would preclude landscape and limit the placement of the Master Plan-required water quality treatment ponds. This potentially pushes this feature toward the river in a series of cascading ponds, which also allows a linear flat open space for gatherings and festivals. The pink dashed line indicates existing grade

Riverfront Alternative 5: Move Pipes Out of the Riverfront Open Space

The new DI is relocated beneath National Western Drive in this Alternative, affording the maximum flexibility in grading back the existing river bank to create habitat restoration areas and giving easy pedestrian access to the river. Without easement restrictions as in Alternative 4, the park areas nearest National Western Drive will benefit from greater ability to flexibly balance flat, usable space with programmatic requirements including water quality and or building such as a river visitor's center.



Recommendations

Development of the full potential of Riverfront Open Space at NWC, and fulfillment of many of the NWC guiding principles, can be most readily accomplished through the removal of the existing aboveground Delgany Interceptor and replacing it with new, buried interceptor pipes within the new, proposed National Western Drive (Alignment C) with Riverfront Alternative 5. The relocation of the Delgany Interceptor to the new National Western Drive provides the broadest range of opportunities for implementing Riverfront Open Space improvements, with only minimal disadvantages. Other alignment options, including relocation of the Delgany Interceptor to an alignment across Open Space (Alignment B) could also fulfill the guiding principles, but they have other, more significant disadvantages and their range of opportunities to fulfill all of the Master Plan guidelines is reduced.

The development of SHR at NWC will provide an economically viable renewable energy source that can reasonably satisfy approximately 60 to 70% of the envisioned heating and cooling energy demands at the NWC, both for Phases 1 and 2 and potentially at full buildout, utilizing the program outlined in the Master Plan. The relocation of the Delgany Interceptor, along with the planning and design of new, centralized heating and cooling facilities to serve the NWC provide a unique and timely opportunity to implement SHR.

- It is recommended that the design and construction of the new Delgany Interceptor within Alignment C should be initiated as soon as funding is identified. This should also include the demolition and disposal of the existing Delgany Interceptor following successful commissioning of the new interceptor.
- It is recommended that the potential for implementation of SHR should be included in the NWC planning and design of the heating and cooling utilities required for the NWC improvements.
- The development of Riverfront Open Space at NWC and fulfillment of many of the NWC guiding principles can be accomplished to varying degrees depending on the final determination of the preferred alignment of the DI and the corresponding selection of a preferred Riverfront Open Space Alternative. This Study provides quantified data and subjective considerations intended to allow an informed decision by the NWCO in selection of a Riverfront Open Space concept. It is recommended that the evaluation criteria and the data and considerations presented herein be reviewed and a preferred DI Alignment and corresponding Riverfront Open Space Alternative should be selected.

1.1 BACKGROUND

The National Western Center (NWC) in north Denver will be approximately 250 acres at full buildout and represents the expansion and redevelopment of Denver's National Western Stock Show campus into a year round center for entertainment, research, education and agribusiness. The NWC is bounded by the South Platte River (SPR) on the west, Brighton Boulevard on the east, Race Court to the north, and McFarland Drive to the south. The location of the NWC, along the Interstate 70 corridor and midway between Union Station and Denver International Airport, makes the NWC an attractive urban investment opportunity.

The Denver City Council adopted a National Western Center Master Plan in March 2015. The Master Plan was created by a collaboration of the City and County of Denver, Colorado State University, the Western Stock Show Association, History Colorado, and Denver Museum of Nature and Science. Partial funding for Phases 1-2 of the Master Plan was approved by Denver voters in November 2015 (Ballot Initiative 2C), and the State's approval of Regional Tourism Act (RTA) funds for the NWC later that same month. The Mayor's Office subsequently created the Office of the National Western Center (NWCO) to oversee the buildout of the campus. An NWC Executive Oversight Committee (EOC) was appointed to oversee the NWC project. The National Western Stock Show, an event held annually since 1906, is a primary component of the NWC project.

The area of study for this work is the land along the South Platte River that will eventually be repurposed as Riverfront Open Space, and contains the above-ground Delgany Interceptor pipes, twin 72" and 78" wastewater pipes that convey sewage to the Robert W. Hite Wastewater Treatment Facility 1.5 miles north of the NWC. Figure 1-1 is a map of the project area, taken from the NWC Master Plan.

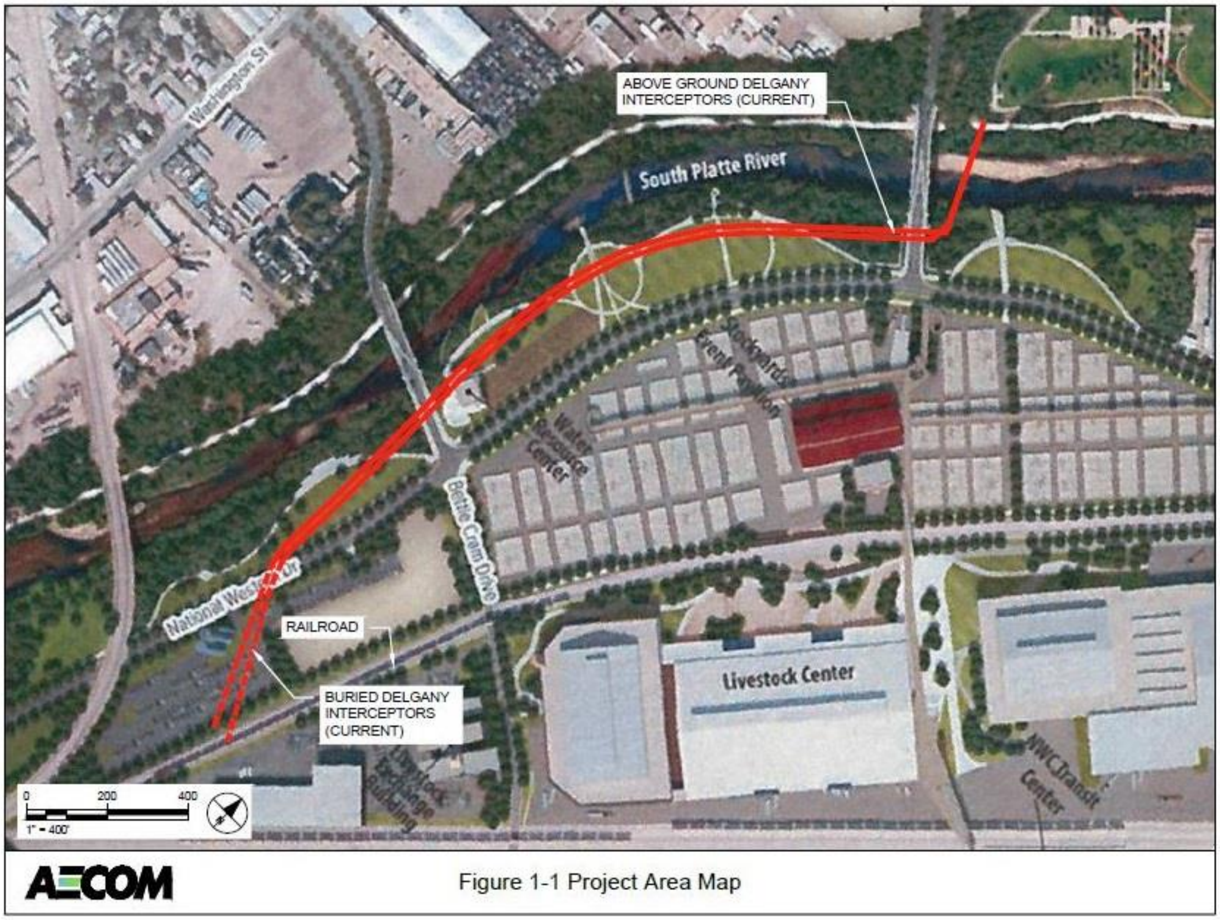


Figure 1-1:
Project Area Map

The Delgany Interceptor originally crossed the South Platte River at the NWC site via an aerial crossing (pipe bridge) over the river. The Delgany Interceptor pipes were constructed aboveground to facilitate their connection to the aerial river crossing and to avoid pressurized flow in the pipes. In the 1970's an inverted siphon was installed to allow a buried crossing of the SPR, and this eliminated the need for the Delgany Interceptor pipes to be aboveground. MWRD took ownership of Delgany Interceptor in 1983 from the City of Denver as part of the Common System Transfer Agreement.

The NWC campus has been the home of the National Western Stock Show and associated livestock industry for over 100 years; historic maps and property agreements related to the National Western Stock Show property are included for reference in **Appendix A**. The site was ideal for the large animal events included in the annual National Western Stock Show events, with its proximity to the South Platte River and other regional surface transportation. The stretch of the South Plate River along the National Western Stock Show parcel is nearly one mile long and is a major feature of the campus. The scope of this Study is limited to the areas between the railroad tracks and the South Platte River in Figure 1-1.

The NWC Master Plan defines nine Guiding Principles including the directive to “Engage the River and Nature” as the campus is redeveloped. The Master Plan recommends:

- Bury or move the Delgany Interceptor
- Create campus-wide connections to the river
- Improve river habitat and health
- Create recreational trails and education areas along the river
- Treat storm water onsite
- Aspire to create net zero or net positive impact on water quality/quantity
- Consider impacts to the South Platte River (SPR) during all stages of the NWC project.

Additionally, the NWC Master Plan has a goal of establishing a “net zero” energy district, prioritizing technical and behavioral strategies to increase efficiency and using on-site renewable energy sources.

This Study is a priority for the initiation of the redevelopment of the NWC. The NWC Master Plan states that design and construction of Phases 1 and 2, as shown in Figure 1-2 NWC Phasing Map from the NWC Master Plan, are planned for implementation over the next 10 years. The South Platte Riverfront area, within the NWC site, is identified in the NWC phasing plan as part of Phase 1.

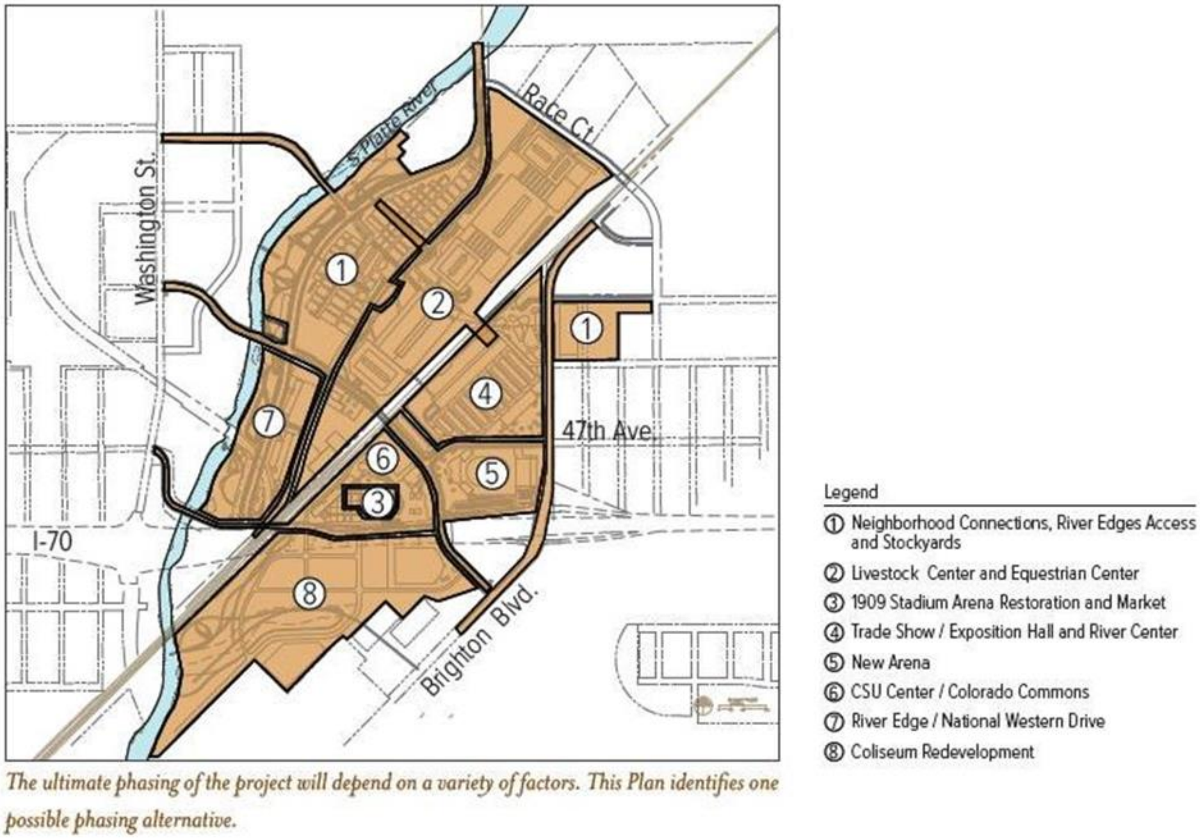


Figure 1-2:
NWC Phasing Map

1.2 PURPOSE

The purpose of this Study is to address the NWC Master Plan recommendation to create new publicly accessible open space, habitat improvements and regional trail linkages along the SPR as part of the NWC project. This Study satisfies its purpose by focusing on the Master Plan guiding principle of bury or move the Delgany Interceptor, with additional attention to related Master Plan guiding principles of campus-wide connections to the river, improve river habitat and health, create recreational trails and education areas along the river, and treat storm water on site. In addition, this Study addresses the decision of whether or not to relocate the Delgany affects the potential for implementation of Sewer Heat Recovery technology. The efforts needed to satisfy the purpose include three separate but related tasks:

1. Evaluate possibilities related to "re-purposing" or re-locating the existing Delgany Interceptor pipes, as well as assessing options related to Lift Station #5.

2. Evaluating options for taking advantage of the proximity of the Delgany Interceptor within the NWC to develop a Sewer Heat Recovery system as a renewable energy source

3. Develop concepts to “Engage the River and Nature” by improving the NWC connectivity to the Riverfront and incorporate the alternatives for re-purposing or re-locating the Delgany Interceptor.

The Delgany Interceptor, owned and operated by the Metro Wastewater Reclamation District (MWRD) is a major factor in all three of the tasks performed for this Study. The NWC connection to the South Platte River is impacted by the presence of the Delgany Interceptors. The Interceptors’ above grade, prominent location along the SPR is a barrier to connectivity and is the reason this issue is highlighted in one of the NWC Master Plan’s Guiding Principles: Engage the River and Nature. This connection is critical to the development of the NWC since it rightly places focus on the river by bringing people to its edge. This creates the need to bury, move or create connections across the above-ground segment of the Delgany Interceptor at NWC.

The Delgany Interceptor is also a valuable opportunity to address the net-zero energy goal in the re-development of the NWC. Sewer Heat Recovery (SHR) has been identified as an opportunity to provide thermal energy as a resource to the NWC. The recovered thermal energy can be used to reduce the demand for electricity and natural gas at the NWC, and SHR would also facilitate the reduction of sewage temperature in the Delgany Interceptor, which is an important goal for MWRD.

This Study presents the analyses and evaluations that address the three primary National Western Center questions related to the Delgany Interceptor, and it focuses on the challenges and benefits that Delgany Interceptor offers to the NWC. This Study also provides recommendations and an implementation plan for phasing and construction of the selected NWC improvements.

2.1 NATIONAL WESTERN CENTER (NWC) SITE

2.1.1 Existing Conditions

2.1.1.1 Delgany Interceptor and the South Platte River Inverted Siphon

The approximately one mile long stretch of the South Platte River (SPR) adjacent to the National Western Stock Show is virtually inaccessible due in part to the above ground location of the Delgany Interceptor. The Interceptor includes dual, parallel Metro Wastewater Reclamation District (MWRD) sanitary pipelines with diameters of 72 inches and 78 inches. A 1900-feet long segment of the Delgany Interceptor lays on the ground along the east bank of the SPR, roughly from the MacDonald Farms property at the south end of NWC to the Denver Rock Island Railroad maintenance facility at the north end. The interceptor flows into an inverted siphon to cross beneath the South Platte River at approximately 50th Avenue on its way to MWRD's Robert W. Hite Treatment Facility, located approximately 1.5 miles north of the NWC.

The inverted siphon that crosses the SPR at the downstream end of the Delgany Interceptor carries wastewater flows from the Delgany Interceptor and from the City of Denver's Lift Station #5. Lift Station #5 is at the lowest elevation within the neighborhoods north and east of the NWC, and the wastewater flows by gravity from those neighborhoods to Lift Station #5. Lift Station #5 "lifts" the collected wastewater to a higher hydraulic elevation that allows the collected wastewater to mix with the Delgany Interceptor flows at the SPR inverted siphon.

The SPR inverted siphon consists of:

- An aboveground structure that receives flows from the Delgany Interceptor and from the City of Denver's Lift Station #5.
- Twin 60-inch diameter siphon pipes that exit down from the aboveground siphon structure and drop to an elevation of approximately 5120 feet at the pipe invert; the siphon pipes extend across the river in a northwesterly direction, approximately perpendicular to the river. The tops of the siphon pipes are approximately 7 feet below the bed of the South Platte River.
- A junction structure on the west side of the SPR that connects the siphon pipes with existing 90-inch diameter interceptor parallel to the west side of SPR.

The siphon pipes that exit down from the aboveground siphon structure on the east side of the SPR have a vertical drop of more than 20 feet, and they allow the opportunity for new Delgany Interceptor pipes to be installed and connected to the siphon at a lower invert elevation than the existing Delgany Interceptor. Additionally, any new Delgany connections at the siphon must accommodate the Lift Station #5 flow contributions, with the possibility of modernizing and downsizing the footprint of Lift Station #5 and reducing the size and burying the force main to the SPR Siphon and reducing the visual impact at the north end of NWC.

2.1.1.2 National Western Drive and Denver Rock Island Railroad Tracks

Significant surface features on the existing NWC site include National Western Drive and the Denver Rock Island Railroad tracks. Both of these features are east of the Delgany Interceptor, and they cross the NWC roughly diagonally from the southwest corner of the site to the northeast corner. As they exist, National Western Drive and the Railroad Tracks are obstacles to the future development of NWC, and the NWC Master Plan defines new, relocated corridors for each of them. The analyses and evaluations performed herein are based on the understanding that the relocations of National Western Drive and the Denver Rock Island Railroad tracks will be completed prior to the initiation of construction work related to the re-purposing or relocation of Delgany Interceptor and the improvements to the Riverfront Open Space.

2.1.1.3 South Platte River Floodway

The South Platte River (SPR) acts as a major stormwater conveyance for the Denver metropolitan area. The US Army Corps of Engineers (USACE) manages dam releases from three upstream flood control reservoirs (Chatfield, Cherry Creek, and Bear Creek), however, the river's 100-year flood flows are dominated by uncontrolled storm runoff. The SPR is mapped as a Special Flood Hazard Area (SFHA) by FEMA and is therefore subject to Federal, State and City floodplain regulations. The Urban Drainage and Flood Control District (UDFCD) has recently re-analyzed the South Platte River hydrology and hydraulics and developed the 100-year flood elevations for the SPR adjacent to the NWC. The scope of improvements adjacent to the SPR must not include any changes that would result in an increase in the 100-year flood elevation of the SPR. This is referred to as a "no-rise" condition. Due to adverse impact considerations and the presence of an existing flood control levee system on the west bank, the scope of work for this Study was amended to include computerized hydraulic simulations (using USACE HEC RAS software) and analysis of the proposed Riverfront Open Space modifications and improvements to confirm that none of the recommended alternatives would violate the no-rise criteria for the SPR.

2.1.2 NWC Master Plan

The National Western Center (NWC) project is an approved redevelopment of 250 acres including the National Western Stock Show and surrounding areas. The project involves five partners: City and County of Denver, Colorado State University, Western Stock Show Association, History Colorado and Denver Museum of Nature and Science. A NWC Master Plan was adopted by City Council in March 2015. The NWC Master Plan's vision is as follow: "The National Western Center celebrates the pioneering spirit and promise of the West through year-round experiential life-long learning, the arts, entertainment, competition and commerce."

The NWC Partners and the community established nine Guiding Principles for the integrated development of the site:

- Community and Neighborhood Integration
- Engage the River and Nature
- Celebrate Western Heritage
- Inspire health and Wellness
- Build cultural Crossroads
- Be Pioneering: Break Trail and Foster Innovation
- Create Fun and Entertaining Experiences
- Grow local, Regional, and Global Intelligence
- Embrace an Ethic of Regeneration

The NWC Master Plan recommends creating new publicly accessible open space, habitat improvements and regional trail linkages along the South Platte River (SPR) as part of the NWC project.

2.1.3 US Army Corps Urban Waterways Restoration Study

The US Army Corps of Engineers (USACE) and Denver Public Works initiated the South Platte River Multipurpose Improvements Feasibility Study and Environmental Impact Statement (EIS), also known as the Urban Waterways Restoration Study. The study applies to a 7-mile stretch of the South Platte River from roughly 2,000 feet upstream of 6th Avenue to 58th Avenue. The 7-mile stretch includes the much smaller area of the riverfront that is the center of this Study, and identifies it as Reach 2. Major improvements are recommended for Reach 2, including:

- Relocate the Delgany interceptor to the east
- Widen and regrade the east bank
- Add wetland benches and jetties to improve aquatic habitat
- Remove invasive species and replace with native vegetation

The Study is ongoing and will be brought to USACE leadership for approval in 2018. No funding for the recommendations has been identified at this time.

2.2 PROJECT TEAM

2.2.1 Project Management Team

Denver voters approved the NWC Master Plan in November 2015 and the Mayor subsequently created the Mayor's Office of the National Western Center (NWCO) to oversee the project on behalf of the City. The NWCO Director, with guidance from appropriate stakeholders, including the Equity Partners together with MWRD must determine whether to keep the Delgany Interceptor at its current location or relocate the pipeline away from the riverfront. More information is needed about both scenarios in order for the MWRD, and the Equity Partners to make an informed decision. The NWCO Director identified a multi-disciplinary Project Management Team (PMT) to oversee the present Study. The members of the PMT are shown in the project Organization Chart (Figure 2.1).

Communication and coordination between all team members and partners is a key component of the scope of work. A Study work plan was prepared to describe the project approach and to integrate the separate but related analyses, including a schedule with requirements for deliverables and critical milestones. The work plan was updated as needed during the execution of the project. The project included several work sessions and presentations, including:

- A Project Kickoff meeting
- Six project work sessions with the Project Technical Teams
- Four partner coordination meetings, including with MWRD and with the MWRD consultant team for Sewer Heat Recovery
- Eight Bi-Weekly Project Management Team meetings
- Two meetings with the Procurement Advisors
- One presentation to the NWC Executive Oversight Committee
- Two presentations to the NWC Citizens Advisory Committee
- One presentation to the MWRD Board

Agendas, meeting minutes, and presentation materials were prepared for all meetings and presentations.

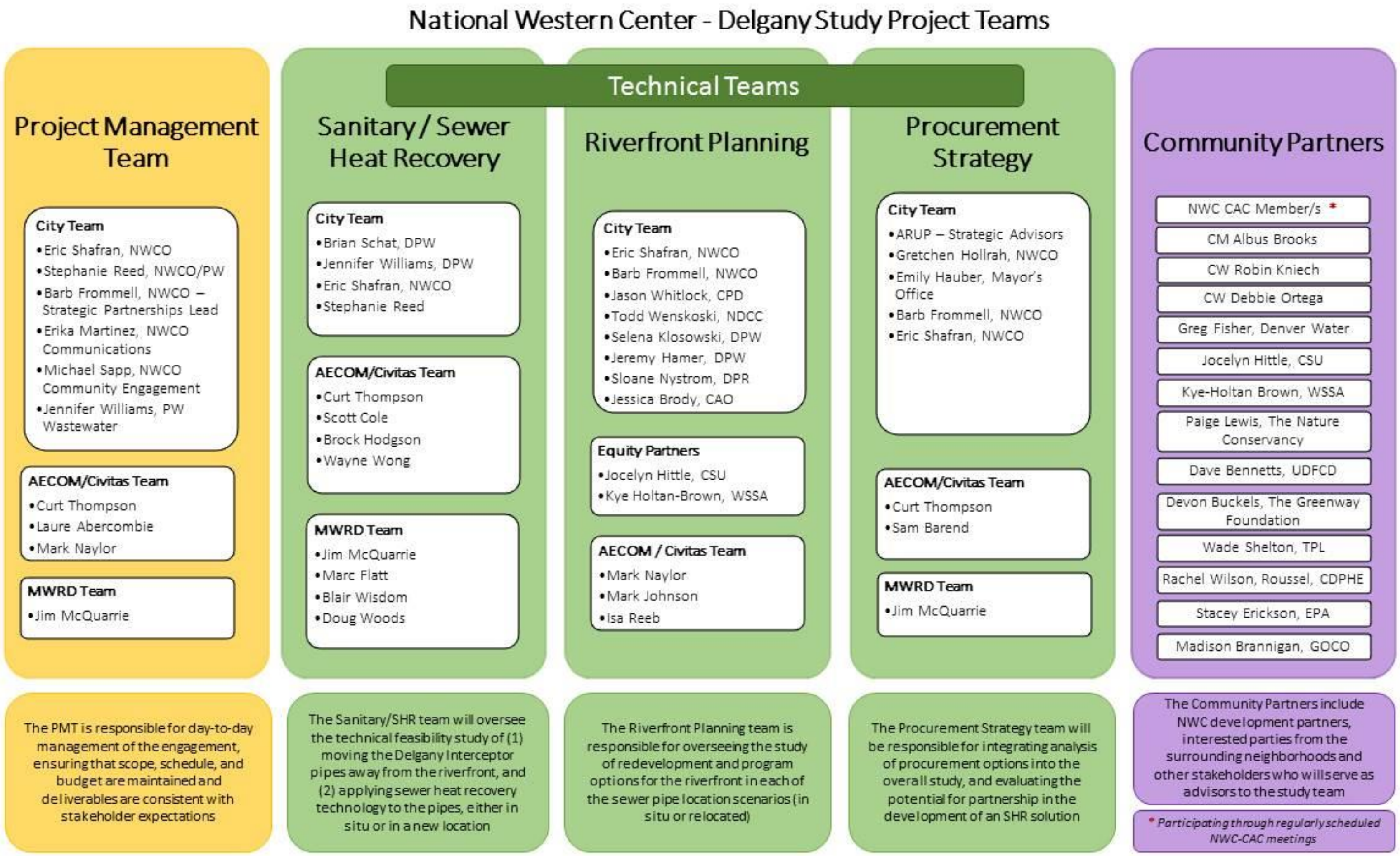


Figure 2-1:
Organization Chart

The PMT is responsible for day-to-day management of the engagements, ensuring the scope, schedule, and budget are maintained and deliverables are consistent with the community expectations.

2.2.2 Technical Advisory Groups

Three technical advisory groups were created by the PMT to discuss and provide feedback on specific aspects of this Study:

- **Sanitary/Sewer Heat Recovery Technical Team**: the team oversaw the technical feasibility study of relocating the Delgany Interceptor pipes away from the riverfront, and of applying sewer heat recovery technology to the pipes, either in situ or in a new location.
- **Riverfront Planning Technical Team**: the team oversaw the study of riverfront planning and redevelopment program alternatives for various sewer pipe alignments.
- **Procurement Strategy Technical Team**: the team was responsible for evaluating procurement strategies for potential funding and financing of the capital and life-cycle costs, and evaluating alternative procurement options and potential for partnership in the development of a Delgany Interceptor relocation and SHR investment.

2.2.3 Community Partners

A diverse group of stakeholders, including representatives from the National Western Center Citizens Advisory Committee (CAC), City Council, NWC development partners and other regional stakeholders with aligned interests advised the study.

2.3 ENGINEERING AND RIVERFRONT CONCEPT ANALYSES

2.3.1 Delgany Interceptor Alignment Analysis

The first step of the Delgany Interceptor Alignment Analysis scope of work is collecting data from the field, from the City and County of Denver, Denver Water and MWRD. The available data includes as-built records, GIS databases and mapping of the existing facilities and utilities, the NWC Master Plan and Master Infrastructure Plan, hydraulic computer models, and flow metering data.

The following tasks and deliverables define the scope of work for the alignment analysis and evaluations. Assumptions and proposed design criteria must be documented, and an evaluation methodology must be developed. For each analysis, the following must be addressed:

- Conceptual design
- Land Footprint
- Maintenance and Operation Impacts
- Constructability
- Environmental impacts
- Construction Phasing and proposed schedule
- Other considerations related to the alignment evaluation criteria as determined by the Project Management Team

The alignment analysis included up to three “relocate” alignments, one “in situ” alignment (e.g. bury the pipe), and one baseline “status quo” or “do nothing” option. Identification and screening of alignments was performed in close coordination with the Riverfront Open Space analysis and the Sewer Heat Recovery screening, and in consultation with MWRD. The analyses and evaluations are documented and summarized in this Study.

2.3.2 Sewer Heat Recovery (SHR) Screening Analysis

The scope of work for the SHR screening analysis also includes collecting data from the City and County of Denver and MWRD. The data needs include wastewater quality, temperature, and flow rates; the data sets that were collected for this assignment are summarized below:

- Delgany Interceptor flow data January 2012 - December 2016 (files: dgc2a.csv & dg5.csv, MWRD)
- Delgany Interceptor temperature data, January 2016 - May 2016 (file: Attachment G - MWRD Temp and Flow data.xls, MWRD)
- Robert W. Hite WWTP quality data, January 2015 - January 2017 (file: Wastewater Characteristics (2 years).xls, MWRD)
- - Robert W. Hite WWTP effluent temperature, January 2009 - December 2016 (file: North and South Final Effluent Temperature 2009-2016.xls, MWRD)

The following tasks and deliverables define the scope of work for the screening level analysis for implementing SHR at the NWC campus. Assumptions and proposed design criteria must be documented, and an evaluation methodology must be developed. For each SHR system considered, the following must be addressed:

- Analysis of the potential campus heating and cooling demands vs. the potential supply from the interceptor
- Opportunities and constraints as they relate to NWC and the Delgany Interceptor
- Relative costs, capacity and constructed examples of each types of SHR system
- Assessment of the ability of each system to satisfy the evaluation criteria and to be implemented, for various Delgany alignments
- Operational impacts for the Delgany Interceptor and for the NWC
- Environmental impacts
- Constructability

2.3.3 South Platte Riverfront Conceptual Design Study

The scope of work for the SPR Conceptual Design Study includes developing and comparing design alternatives for the riverfront at the NWC in order to demonstrate how the current locale of the Delgany or a future, relocated Delgany Interceptor will affect the options and challenges related to the Riverfront Open Space development and the opportunity for the full riverfront experience.

Assumptions and evaluation criteria must be documented, and an evaluation methodology must be developed and utilized. For each Riverfront Open Space development alternative, the following must be addressed:

- Opportunities to improve wildlife habitat and incorporate on-site stormwater treatment, green infrastructure or other quality features
- Quantification of all landscape features
- NWC Master Plan and Urban Waterways Restoration Study goals and evaluation criteria
- Environmental impacts
- Constructability
- Funding Opportunities

Confirm that the proposed alternative Riverfront Open Space improvements adjacent to the SPR do not include any changes that would result in an increase in the 100-year flood elevation of the SPR. The scope of work for this Study was amended to include computerized hydraulic simulations (using USACE HEC RAS software) and analysis of the proposed Riverfront Open Space modifications and improvements to confirm that none of the recommended alternatives would violate the “no-rise” criteria for the SPR. The HEC RAS computer simulations included refinement of the existing computer model through the addition of intermediate river cross sections to define existing conditions, and incorporation of proposed, revised ground topography along the east side of the SPR to modify the model data to reflect the studied Riverfront Open Space Alternatives.

2.3.4 Proposed Implementation Plan

A proposed implementation plan that addresses the constructability and phasing issues related to the design alternatives for relocating Delgany Interceptor, development of an SHR system, and the development of the Riverfront Concepts must be prepared. The implementation plan must address constructability findings for the preferred alternative and alignment, and a schedule that estimates the time needed for engineering, land acquisition, procuring construction contractors, preparation of the site for construction and the construction and commissioning of the proposed facilities.

3.1 BACKGROUND

The Delgany Interceptor is a critical infrastructure feature that must be addressed in the redevelopment of the National Western Center. The decision of whether to leave the Delgany in place and develop around it, or replace the Delgany Interceptor with new pipes re-located away from its current, prominent location requires consideration of many factors, including but not limited to cost, environmental impacts, accessibility, hydraulics, and impacts on other site infrastructure. Various analyses of possible Delgany interceptor alignments are presented herein to facilitate and inform the selection of a preferred alignment. Most of these analyses were performed in close coordination with the Sewer Heat Recovery Screening and the Riverfront Concept Alternatives that are also a part of the Phase 1 Redevelopment at the National Western Center.

3.2 ASSUMPTIONS, CONSTRAINTS, AND DESIGN CRITERIA

The features and the Master Plan development plans for the National Western Stock Show site, combined with the existing Delgany Interceptor infrastructure, present many constraints and variables that must be understood and defined as part of the alignment evaluations. Assumptions that guide the focus of the analyses and evaluations include:

Assumptions

- The NWC Master Plan is the guiding document for the riverfront redevelopment, and all Delgany Interceptor alignment options must consider the near-term and long-term plans for the NWC site.
- One of the primary objectives of the NWC Phase 1 development is to improve the site connectivity and visitor access to the South Platte River. All relocation alignments must consider this objective.
- All necessary land acquisition to consolidate the footprint of the NWC is being done by the City of Denver. Land acquisition is not an issue to be considered for the alignment options.
- Critical features of the existing Delgany Interceptor, including the flow control manhole near Interstate 70 and the inverted siphon crossing of the South Platte River (described in Delgany Constraints below), define the upstream and downstream limits of relocation alignments.
- The existing Delgany Interceptor inverted siphon structure at the South Platte River can be modified in its drop pipes below the existing siphon structure to allow the connection of new interceptor pipes to the existing siphon. This assumption has been reviewed and accepted by MWRD.
- All alignments under consideration must start and end within the NWC boundaries.
- Potential alignments must not cause a rise in the 100-year floodplain.
- The selected alignment and associated Riverfront Open Space alternative will be considered "Existing Conditions" for the Urban Waterways Restoration study.

Delgany Constraints

Many of the constraints related to the Delgany Interceptor (DI) are due to the location of the DI relative to the South Platte River and the location of some of its key features. Refer to Figure 3-1 for the locations of the Delgany Interceptor's key features.

- The existing inverted siphon beneath and across the South Platte River is a critical component to the MWRD collection system that cannot be reasonably relocated without significant cost and off-site impacts. Additionally, relocation of the siphon would impact the operations of the City of Denver’s Lift Station #5. The siphon is located near the north end of the National Western Stock Show site, and the siphon defines the “destination” (i.e. downstream limit) for all Delgany Interceptor alignment options.
- The South Platte River (SPR) acts as a major stormwater conveyance for the Denver metropolitan area. Currently the 100-year flood level of the SPR approximately matches the base of the DI cradle. Modifications to the river (especially along the east bank) that result in a rise in the 100-year flood elevation are not allowed.
- The siphon pipes that exit down from the aboveground siphon structure on the east side of the SPR have a vertical drop of more than 20 feet, and they allow the opportunity for new Delgany Interceptor pipes to be installed and connected to the siphon at a lower invert elevation than the existing Delgany Interceptor.
- The existing Delgany Interceptor is within an easement that limits the use of land above the pipes and within the easement. These limitations include restrictions on vegetation growth (e.g. no trees) and types of surface conditions that facilitate access to the pipes. New relocated Delgany Interceptor pipes would be subject to the same or similar land use restrictions. The new easement would have a minimum width of 35 feet and would extend the full length of the pipes.
- The flows within the two pipes of the existing Delgany can be diverted or shut off (within one of the pipes at a time) at a diversion structure at the south end of the site and shortly upstream of the site. The diversion structure allows flow control between both interceptors. Per MWRD, this diversion structure is a key element of the MWRD collection system, and this structure defines the upstream limit for all Delgany Interceptor alignment options.
- The Delgany Interceptor requires periodic operational flushing and maintenance inspection and repairs to maintain its full hydraulic capacity and reliable service. The operation and maintenance activities require access manholes to be provided at approximate 400-feet intervals along the pipes at a minimum, with spacing up to 800-feet for straight sections. Maintenance truck access to each manhole is required. This is a critical requirement that must be addressed for every alignment option, including the in situ option for the existing Delgany Interceptor.

Figure 3-1:
Map-Delgany Interceptor at NWC

Design Criteria

- New Delgany Interceptor conduits must be circular pipes. Conduits with elliptical, rectangular, or square flow areas are not acceptable. This requirement is to maintain consistency with other MWRD collection system conduits and to allow continued use of existing MWRD maintenance and inspection equipment.
- New Delgany Interceptor pipes must have a minimum 60-inch diameter. This minimum size requirement allows continued use of existing MWRD maintenance and inspection equipment.
- There must be a minimum of two (2) Delgany Interceptor pipes. This requirement is to maintain the current level of operational flexibility and redundancy of the existing Delgany Interceptor.
- New Delgany Interceptor pipes must be of glassfiber reinforced (fiberglass) plastic materials. MWRD experience has indicated that this material provides the preferred combination of hydraulic properties, structural strength, and corrosion resistance for the size and conditions of the Delgany Interceptor.
- Access manholes for new Delgany Interceptor pipes must be provided at approximately 400 feet intervals (on each pipe) along the pipeline alignment. This requirement is to allow continued use of existing MWRD maintenance and inspection equipment. Greater intervals of up to 800 feet between manholes may be allowed to accommodate site-specific conditions, but they must be coordinated with MWRD.
- Maximum flow velocities within new Delgany Interceptor pipes cannot exceed 10 feet per second without engineering review and analysis to assure that a flow velocity greater than 10 feet per second is acceptable.
- The maximum water depth (d) to diameter depth (D) ratio of D/d, for calculating the nominal capacity of the pipes, cannot exceed 0.80.

3.3 ALIGNMENT OPTIONS

The alignment options described below were developed in coordination with the Riverfront Open Space Alternatives. Each interceptor alignment was identified as a reasonable option that satisfies the constraints and assumptions applicable to the alignments, and that provides new opportunities related to the Riverfront Open Space. The interrelationship between the interceptor alignments and the Riverfront Alternatives are as shown in the Table 3-2, below.

Table 3-1:
Relationship Between Interceptor Alignment and Riverfront Alternative

Interceptor Alignment	Riverfront Alternative
A. *In Situ* – remains in its current location	1. Pipe remains exposed, and is bridged over
	2. Partially buried on the east side
	3. Fully buried; “bermed” over
B. Pipes moved to the east, but still within the open space	4. Fully buried within the eastern portion of the open space
C. Under National Western Drive	5. Pipes out of the open space
D. Under the Stock Yards	
E. Under or adjacent to the consolidated rail corridor	

Approximate locations of the Alignments are shown in Figure 3-2 on the next page.

Each of the Alignments was reviewed from a constructability perspective and to identify any possible limits the Alignment might impose on NWC development in the future. This initial review identified two alignments, Alignment D and Alignment E, that present likely conflicts with proposed NWC infrastructure and site uses. The likely conflicts for each alignment are:

Alignment D – The location of Alignment D under the Stock Yards presents several utility conflict and site use issues. The Stock Yards will require extensive site infrastructure for water supply, drainage, and waste management. The likelihood of conflict between the Stock Yards infrastructure and the relocated Delgany Interceptor is very high. Additionally, the density of 'animal population' within the Stock Yards, as well as the high and dense utilization of the site is likely to conflict with MWRD requirements for access to the Interceptor for operation and maintenance activities.

Alignment E – The location of Alignment E along the western edge of the rail corridor, illustrated in the diagram to the right, presents a direct, unworkable conflict with a pedestrian underpass (red circle) needed to allow pedestrian access to the east and west of the railroad spur through the site. Relocation of the DI pipes to Alignment E would preclude this pedestrian underpass due to lack of vertical clearance of the pipes relative to the elevation of the walking surfaces. Other options for crossing the underpass would require significant capital cost and would create operation and maintenance issues.

Alignments D and E were eliminated from further consideration due to their conflicts with and limits on future NWC site development. Alignments A, B and C were retained for additional evaluation and consideration.

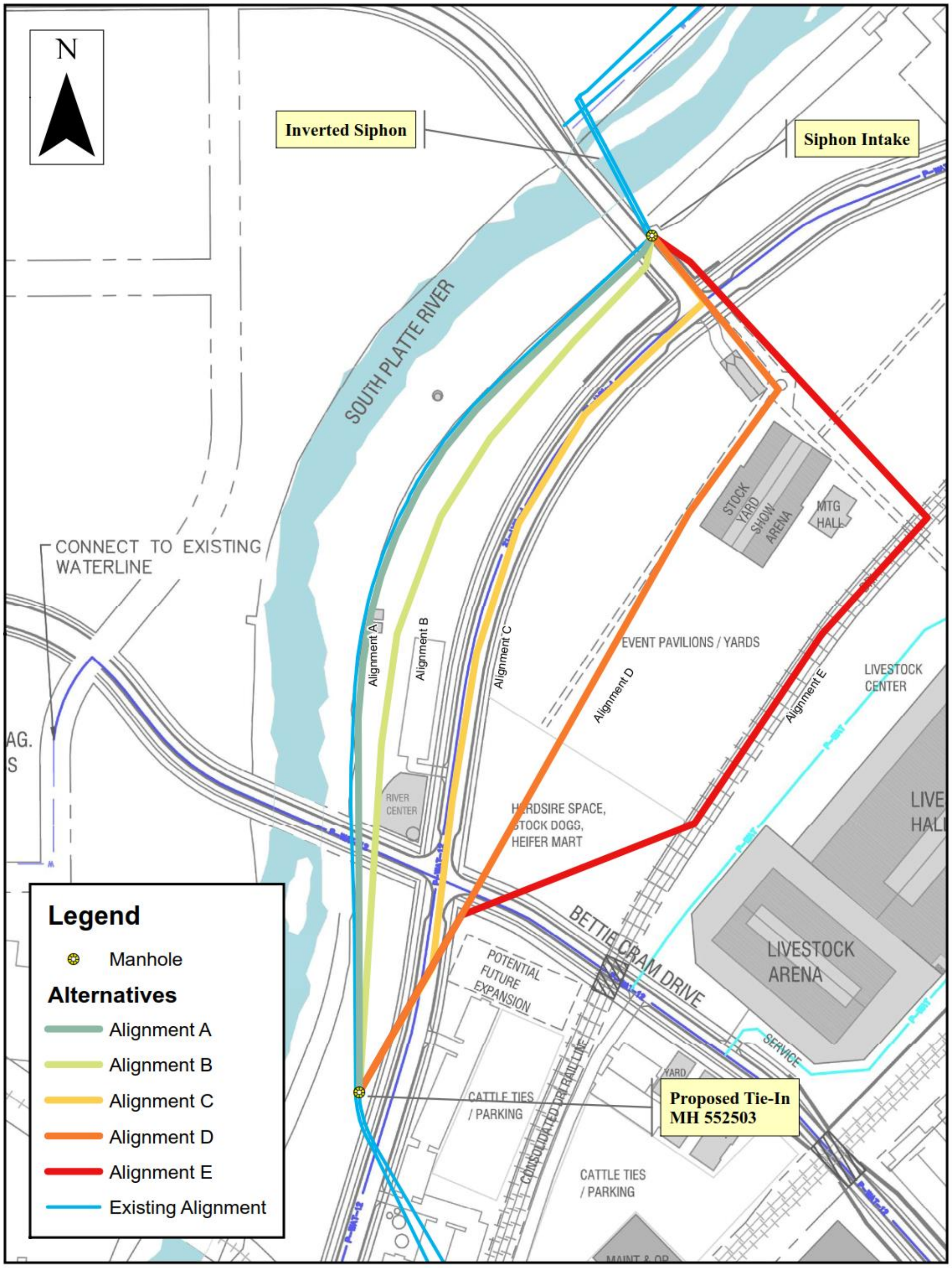


Figure 3-2:
Delgany Interceptor Alignment Options

3.3.1 Alignment A – in situ

This alignment does not include relocating the Delgany Interceptor. The existing pipes remain in place, and Riverfront Open Space Alternatives 1-3 involve improvement over and around the existing pipes to meet the programmatic goals of the Master Plan. The riverfront improvements must accommodate MWRD requirements for operation and maintenance access to the interceptor manholes. This alignment has minimal impacts to the Delgany Interceptor and to the current site. Key aspects of this option are:

- Delgany Interceptor Impacts:
  - No hydraulic impacts
  - No structural impacts
  - No impacts to current site uses
  - No environmental impacts
- Impact on Riverfront Open Space Alternatives:
  - Limits opportunities for improving connectivity to the riverfront
  - Limits the slope grading options for redevelopment of the site

3.3.2 Alignment B – Relocate Delgany pipes to Open Space, Buried next to National Western Drive (NWD)

This alignment includes relocating the existing Delgany Interceptor pipes to the Open Space immediately east of the existing Delgany. The new pipes would be buried, and the existing pipes would be removed and disposed. The depth of soil cover over the new pipes would vary along the pipe alignment, but in no case would the depth of cover be less than two (2) feet. A concept level plan and profile of the proposed Alignment B is presented in Figure 3-3 on the following page.

The burial of the existing pipes must be designed to accommodate the MWRD interceptor requirements for operation and maintenance access to the interceptor manholes. Key considerations of this alignment are:

- Delgany Interceptor Impacts:
  - New pipes replace existing pipes
  - Improved hydraulic capacity and operations
  - Current site uses must be modified to accommodate access requirements to the new interceptor manholes
  - Possible environmental impacts due to removal and disposal of the existing Delgany pipes, and excavation within the NWC site
- Impact on Riverfront Open Space Alternatives:
  - Increased opportunities for improving connectivity to the riverfront
  - Increased slope grading options for redevelopment of the site

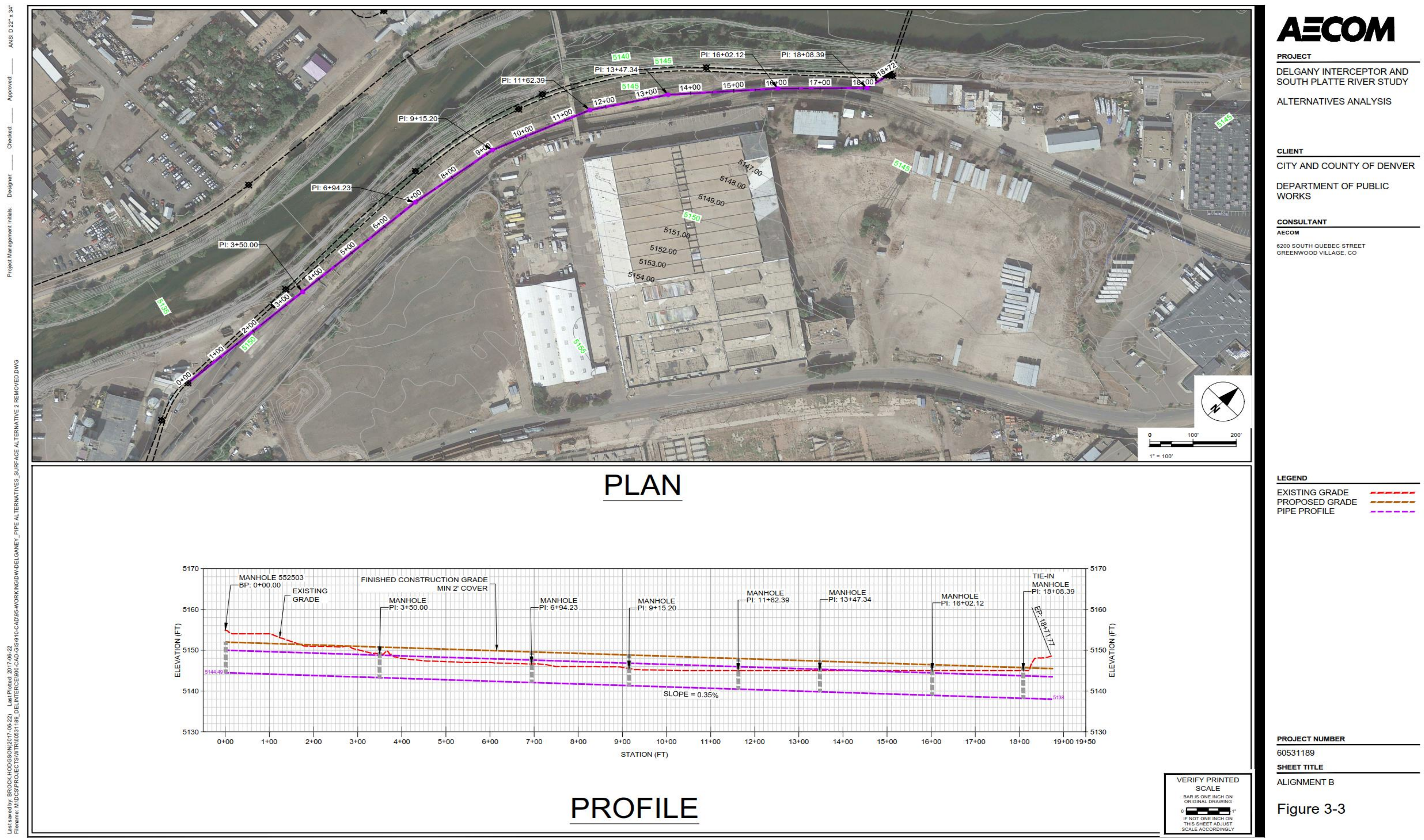


Figure 3-3:
Alignment B Profile

3.3.3 Alignment C – Relocate Delgany pipes under NWD

This alignment includes relocating the existing Delgany Interceptor pipes to beneath the NWD Right of Way. This alignment moves the pipes out of the Riverfront Open Space. The new pipes would be buried, and the existing pipes would be removed and disposed. The depth of soil cover over the new pipes would vary along the pipe alignment, but in no case would the depth of cover be less than two (2) feet. Additional consideration for the subgrade and pavement for the future NWD must also be accounted for in the final grading over the new Delgany Interceptor pipes. A concept level plan and profile of the proposed Alignment C is presented in Figure 3-4 on the following page.

The burial of the existing pipes must be designed to accommodate the MWRD interceptor requirements for operation and maintenance access to the interceptor manholes. Key considerations of this alignment are:

- Delgany Interceptor Impacts:
    - New pipes replace existing pipes
    - Improved hydraulic capacity and operations
    - Current site uses must be modified to accommodate access requirements to the new interceptor manholes
    - Possible environmental impacts due to removal and disposal of the existing Delgany pipes, and excavation within the NWC site
- Impact on Riverfront Open Space Alternatives:
    - Increased opportunities for improving connectivity to the riverfront
    - Virtually unlimited slope grading options for redevelopment of the site

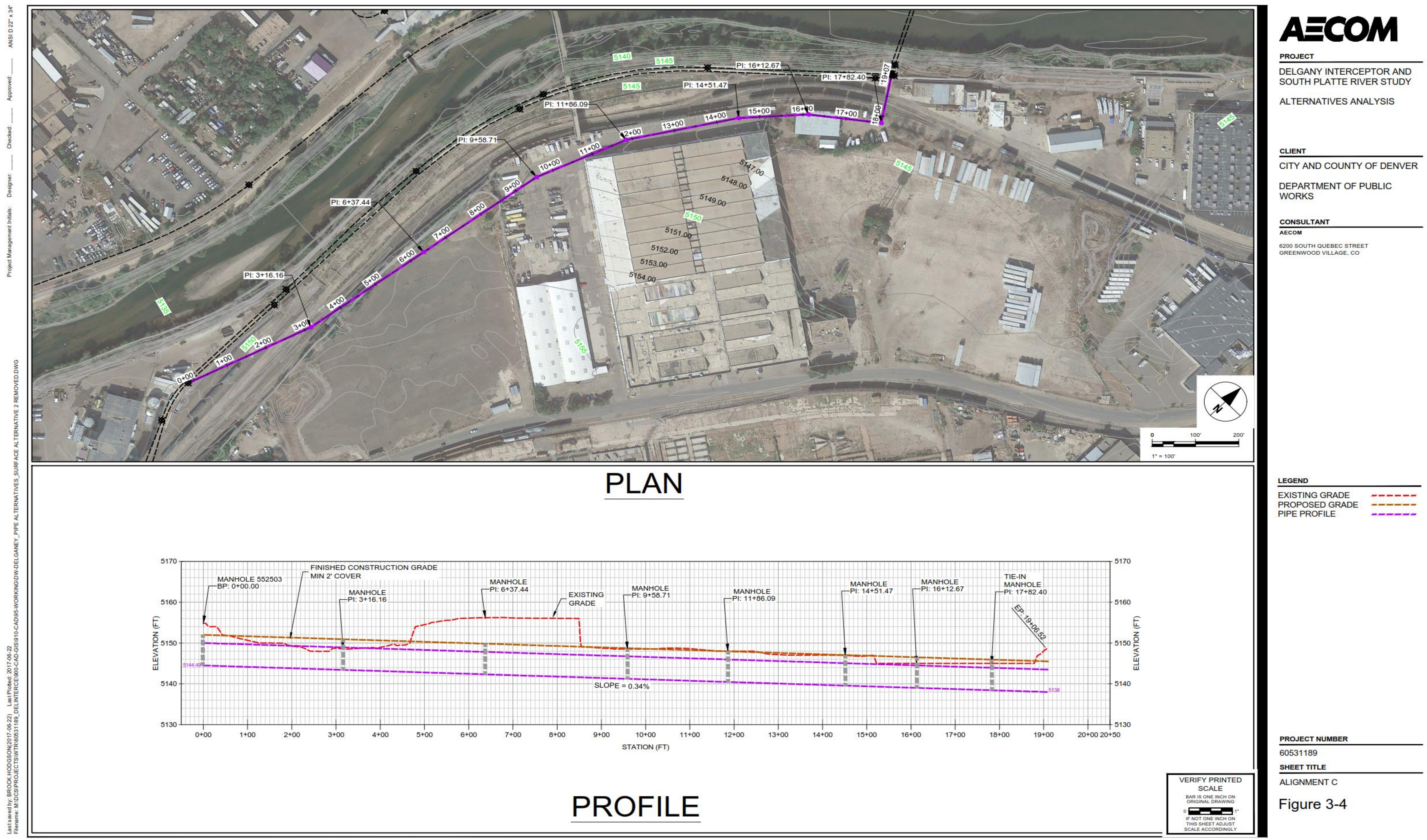


Figure 3-4:
Alignment C Profile

3.4 ALIGNMENT EVALUATIONS

The evaluation process for the Delgany Interceptor alignment options was developed jointly with the Riverfront Open Space Alternatives efforts and the Sewer Heat Recovery (SHR) efforts that are also part of this Study. The flexibility of SHR options resulted in only minimal influence on the alignments options, with the result that the primary focus of the alignment options is to improve the prospects of the Riverfront Development alternatives. Additionally, given the generally limited technical constraints of the various alignment options, the Alignments were tested against the following evaluation criteria:

Table 3-1:
Evaluation Criteria Table for Alignments

Test	Results
Hydraulically and structurally feasible – can the operational requirements of the pipes be achieved from an engineering perspective?	Alignment E presents potential structural challenges with a span over the 250 – 300 foot Livestock Plaza. All other alignments are hydraulically and structurally feasible.
Does the alignment enable the installation of an SHR system	All alignments enable SHR
Does the alignment conform with MWRD operating requirements?	Alignment D may present access challenges to the pipes for maintenance or repairs when the Stock Yards are occupied.
Does the alignment limit or eliminate the ability of the Partners to achieve the NWC programmatic goals outlined in the Master Plan?	Alignment A presents the greatest challenges to achieving the goals related to *Engage the River and Nature*

Based on this short list of evaluation criteria, Alignments A – C are feasible, with Alignment A presenting some limitations on achieving the goals of the Master Plan, which are outlined in the Riverfront Open Space section of this report.

3.5 ALIGNMENT ANALYSES

Three categories of analyses were performed for each of the DI alignment options:

1. Hydraulic analyses to assure that the alignment option would meet or exceed the capacity of the existing DI pipes.
2. Structural analyses to assure that the external loading conditions of the alignment options would not require structural requirements beyond those of typical pipe and hydraulic structure capacities.
3. Constructability analyses to review the required construction processes and identify obstacles or issues related to construction methods, with the goal of reducing or preventing errors, delays, and cost overruns during construction.

Each of these analyses is described in the following subsections.

3.5.1 Hydraulic Analyses

The purpose of the hydraulic analyses is to assure that the capacity of the new, replacement interceptor pipes will not create a hydraulic bottleneck in the MWRD collection system. The hydraulic analyses that were performed included:

- Develop an estimate of the hydraulic capacity of the existing Delgany Interceptor
- Evaluate corresponding pipe diameters and slopes to provide new pipe flow capacities that are approximately equal to or greater than the existing Delgany Interceptor.

The hydraulic capacity of each of the Delgany Interceptor pipes was analyzed separately, to address the different diameters and invert slopes of the existing pipes. A full description of the analysis of each pipe is included in **Appendix B**. The results of this analysis indicate that the nominal, total capacity of the existing Delgany Interceptor is 145 million gallons per day (MGD). At this maximum flow, the primary flow parameters for each of the pipes are shown in Table 3-2.

Table 3-2:
Existing Delgany Interceptor Hydraulic Capacity

Diameter	Slope	d/D	Peak Q, MGD
78”	0.04%	0.80	66.00
72”	0.08%	0.82	79.26
TOTAL			**145.26**

This calculated maximum capacity is described as nominal because the actual, achievable maximum flow through the existing Delgany Interceptor is dependent on the condition of the pipe lining (e.g. smooth or coarse, clean or “clogged”) and on the degree of manhole surcharge that is acceptable in the “flat” segments of the existing pipe.

The hydraulic analysis of relocated, new pipes for the Delgany Interceptor included analysis of pipe diameters of 60-inch, 66-inch, and 72-inch. The siphon pipes that exit down from the existing aboveground siphon structure on the east side of the SPR have a vertical drop of more than 20 feet, and they allow the opportunity for new Delgany Interceptor pipes to be installed and connected to the siphon at a lower invert elevation than the existing Delgany Interceptor. This opportunity to connect to the structure at a lower elevation allows the new pipes to be constructed at steeper grades than the existing interceptor pipes. The hydraulic analyses described herein assumed that the invert elevation of the new Delgany Interceptor connection to the Siphon pipes is 5132.0 feet. This elevation is approximately 12 feet below the top of the siphon pipe, and 12 feet above the bottom elevation of the siphon pipe.

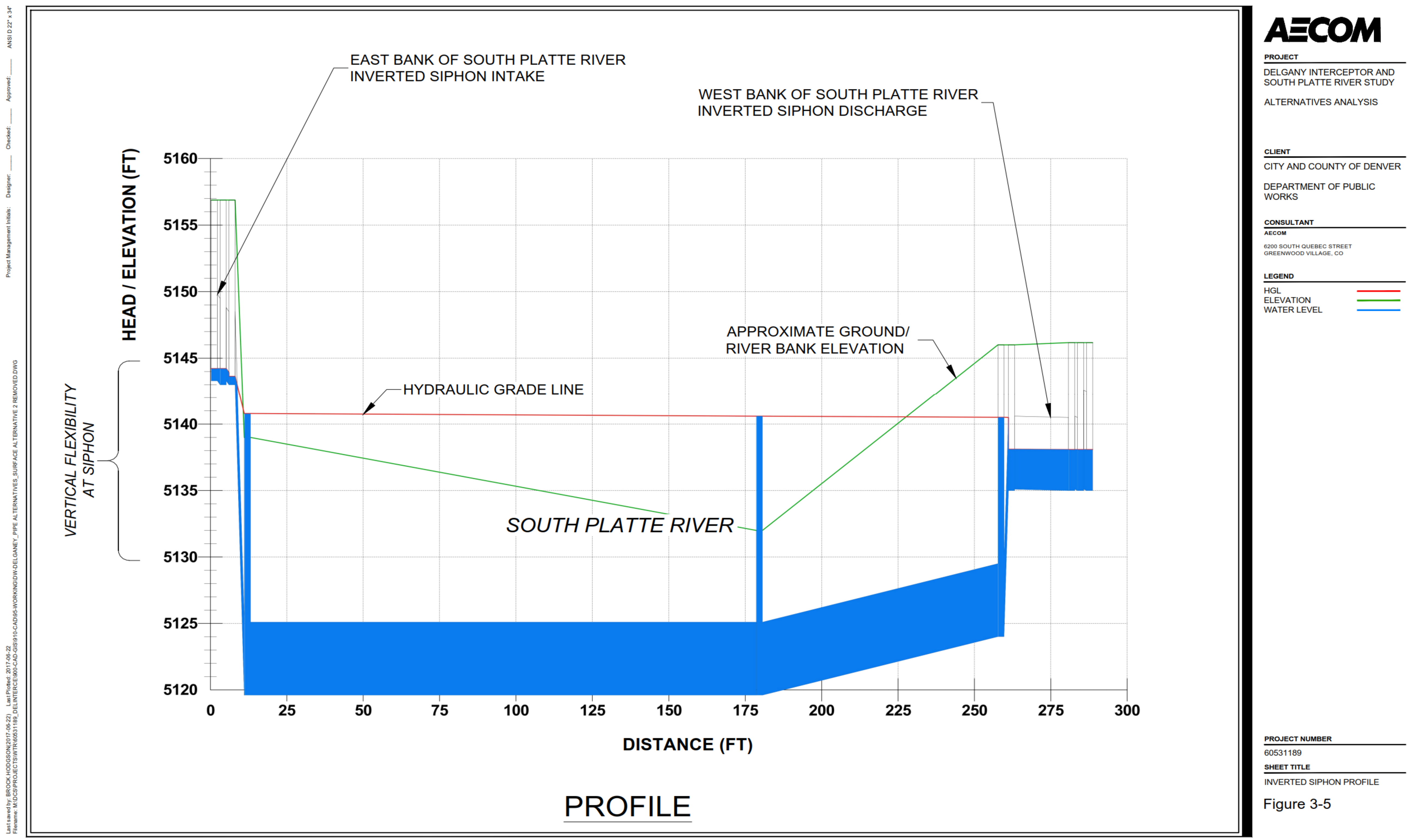


Figure 3-5:
South Platte River Inverted Siphon Profile

The slopes of the new pipes varied from 0.00264 feet per foot to 0.00340 feet per foot. The lengths of the new pipes varied to represent varying lengths of possible alignments. The maximum allowable flow depth in each of the pipes was assumed to be 80% (i.e. D/d = 0.80). The calculated range of the flow capacities is:

Pipe Diameter (Inches)	Invert Slope (feet per foot)	Total Capacity (two pipes) (MGD)
60	0.00264	170
60	0.00340	192
66	0.00264	219
66	0.00340	248
72	0.00264	276
72	0.00340	313

All of the calculated capacities for possible relocated new Delgany Interceptor pipes are greater than the estimated capacity of the existing Delgany Interceptor. The capacities of the 72-inch diameter pipes are approximately twice the capacity of the existing Delgany Interceptor, and the 72-inch diameter pipes are thus eliminated from further consideration. The new, relocated Delgany pipes can reasonably be a minimum of 60-inch diameter to satisfy the minimum pipe diameter constraint, or 66-inch diameter if additional capacity is desired. MWRD has clarified that 60" pipes are more than sufficient to satisfy the current and future demand.

A summary table of the hydraulic calculations for the new, relocated Delgany interceptor pipe size and slope alternatives is included in **Appendix B**.

3.5.2 Structural Analysis

The purpose of the structural analyses is to assure that the structural capacity and integrity of the Delgany Interceptor, whether it is the new, replacement interceptor pipes or repurposing of the existing pipes, will not create new external loading conditions that are beyond the pipes' capabilities or will reduce the pipes' expected service life. The structural analyses that were performed included:

- Evaluate the structural capacity of the existing Delgany Interceptor
- Evaluate the structural capacity of the new Delgany Interceptor pipes to assure that they are capable of supporting the anticipated external loading conditions of the new pipe locations.

The results of the analyses indicate that standard, readily available fiber-reinforced plastic pipe can satisfy the structural conditions and external loading conditions expected for any of the studied alignments.

3.5.3 Constructability Analysis

The purpose of the constructability analysis is to review the possible alignment options to identify construction obstacles or issues related to construction methods that might have the potential to encourage errors, delays, or cost overruns during construction. For this level of concept design for the optional alignments, the term constructability relates to the ease and efficiency with which the proposed infrastructure can be built using standard construction means and methods. An additional, more detailed constructability analysis would typically be performed at the completion of the final design and the construction plans and specifications.

This constructability analysis addresses Alignment B and Alignment C for three distinct aspects of the construction for new Delgany Interceptor pipes –

1. General Construction
2. Pipe Installation
3. Wet Tap Tie-ins to Existing Delgany Infrastructure

Alignment A was not included in this constructability analysis. The analysis of each of these construction aspects as it relates to Alignment B and Alignment C is described in the following subsections.

3.5.3.1 General Construction

General construction issues include but are not limited to site security, access and egress, availability of temporary utilities, space availability for equipment and material storage, and potential conflicts with existing structures and utilities.

- Site Security – The proximity of the project area to existing NWC facilities and surrounding residential and light industry neighborhoods provides a base level of security that can be enhanced through project-specific fencing and lighting. The level of site security provided during construction can be defined by the NWC or left to the discretion (and risk) of the construction contractor. The constructability review did not identify site security issues or concerns that would impact the constructability of the new Delgany Interceptor pipes.
- Access and Egress – The NWC site is highly accessible from Interstate 70, with multiple Interstate exits and entrances within the site vicinity. Additionally, the existing street network and multiple driveway accesses to the site should allow for effective and efficient site access and egress. Access and egress could be hampered slightly by the existing railroad tracks. Site access and egress will be put to the test by pipe delivery trucks, concrete mixing and hauling trucks, earth and debris hauling trucks, and tractor-trailer mobilization and de-mobilization of backhoes, bulldozers, and possibly a mobile crane. The constructability review did not identify site access-egress issues or concerns that would impact the constructability of the new Delgany Interceptor pipes, with the caveat that the City-NWC are responsible for property ownership and easements on the site, and their land and Right-of-Way procurement agents must address the site access and egress requirements as needed.
- Availability of Temporary Utilities – The anticipated need for a contractor's temporary utilities is limited to electricity, water, and sanitation. All of these temporary services are readily available to the NWC site or they can be provided by the construction contractor. The constructability review did not identify temporary utility issues or concerns that would impact the constructability of the new Delgany Interceptor pipes.

- Space Availability – The construction space requirements must address the contractor's need for equipment storage, temporary material storage, construction debris or spoils storage, and facilities for construction supervision and temporary utilities. The total area of storage needed can vary depending on a contractor's methods and means, with the understanding that there is a balance between construction cost and the amount of land available for the contractor's use. It is estimated that the contractor's space requirements for the Delgany Interceptor construction could range from 1 to 3 acres, not including the temporary work areas along the pipe alignment for excavation, backfill, and pipe installation. The existing NWC site currently has adequate open space to satisfy the construction requirements, with the caveat that the City-NWC are responsible for property ownership and easements on the site, and their land and Right-of-Way procurement agents must address the space availability requirements as needed.
- Conflicts with Existing Structures and Utilities – This Study did not include detailed locating of site utilities. The NWC Master Plan indicates that buried utilities within the project area are limited in size and extent. Potential pipe construction conflicts with overhead utilities are not apparent. The existing rail spur that is adjacent to the proposed National Western Drive corridor is planned to be relocated prior to construction of new Delgany Interceptor pipes, and is not expected to impact construction of new Delgany pipes. The constructability review did not identify conflicts or concerns related to existing structures and utilities that would impact the constructability of the new Delgany Interceptor pipes. A more detailed and refined analysis of existing buried and overhead utilities must be performed as part of the final design.

3.5.3.2 Pipe Installation

The constructability review for pipe installation issues includes but is not limited to the soils, geology, and geotechnical conditions along the alignments (including groundwater depth); pipe materials and installation conditions; provisions for MWRD access to the pipes for operation and maintenance; and, accomplishing flexibility in the pipe alignment to accomplish the alignment deviations (curves and changes in direction).

- Soils, Geology, and Geotechnical Issues – The available soils and geologic/geotechnical information is limited to the data provided in the NWC Master Plan. The constructability review for these issues, therefore also considered past, known history of the uses of the site and of past construction on the site. The available data provide a base level of confidence that the soils and groundwater conditions are conducive to new sewer pipe installation, but more detailed information, especially related to soil properties and groundwater depth along a proposed alignment must be determined as part of the final design and preparation of construction drawings and specifications. Historic industrial uses on the site indicate that there is some possibility of deep excavations encountering contaminated soils. Provisions for handling and disposing contaminated soils should be included in the construction plans, pending the collection of additional soils information. The constructability review of soils and geotechnical issues identified the need for collection of additional data prior to completing final design, but there are no apparent issues that would eliminate the possibility of constructing the new Delgany Interceptor pipes along either alignment.
- Pipe Materials and Installation Conditions – The size and materials of the proposed Delgany Interceptor pipes are within the standards of practice for large diameter sewers. There are multiple, reputable manufacturers of the appropriate size and type of pipe needed, and the serviceability of those types of pipe is proven. The installation conditions of the pipe along

either alignment do not present apparent concerns related to depth of bury or other external loading conditions that require atypical or non-standard installation or construction techniques. The final design and construction plans and specifications must address the minimum and maximum depths of bury of the new Delgany Interceptor pipes. The constructability review of pipe materials and installation conditions did not identify issues that would eliminate the possibility of constructing the new Delgany Interceptor pipes along either alignment.

- Access for MWRD Operation and Maintenance – MWRD operation and maintenance activities require that all pipe manholes be accessible by crews using heavy-duty pickup trucks and truck-mounted sewer jetting equipment. Additionally, the access roads to the manholes must be clear and open on a continuous 24/7 basis. Alignment C, with the new Delgany Interceptor pipes installed within National Western Drive will readily satisfy the MWRD access requirements, with the issue of traffic control needing to be addressed for all access. Alignment B, with the new Delgany Interceptor pipes installed within Riverfront Open Space, will require some provisions for reinforced or paved earth surfaces for access roads to the manholes. There are several typical road/path designs that can satisfy the MWRD access requirements. The constructability review of MWRD access requirements did not identify issues that would eliminate the possibility of constructing the new Delgany Interceptor pipes along either alignment.
- Pipe Alignment Flexibility – The alignment options for the new Delgany Interceptor pipes require that the pipes must accommodate curves and possibly abrupt changes in direction. Standard methods for accommodating this alignment flexibility are to achieve minor pipe deflections through “pulled joints” that allow for small (1 to 2 degrees) changes in direction at each pipe joint, or the use of manholes to accomplish larger changes in direction (up to and occasionally greater than 90 degrees). The manholes can also serve the dual purpose of providing access for pipe maintenance. The constructability review of pipe alignment flexibility did not identify issues that would eliminate the possibility of constructing the new Delgany Interceptor pipes along either alignment.

3.5.3.3 Wet-Tap Tie-ins to Existing Delgany Interceptor Infrastructure

The most critical constructability issue for the construction of new Delgany Interceptor pipes is the constraint that the existing Delgany Interceptor <u>cannot</u> be removed from service at <u>any</u> time. This requires that wet-tap tie-ins must be accomplished at the upstream and downstream connections of new Delgany Interceptor pipes to the existing Delgany Infrastructure. The upstream and downstream connections of new Delgany Interceptor pipes must be accomplished while the flows in the existing Delgany Interceptor pipes are continuously conveyed through the Delgany Interceptor pipe(s) and through the existing SPR Siphon to the MWRD Interceptor on the west bank of the SPR. Fortunately, this constructability issue and operational constraint is alleviated significantly by the operational flexibility that MWRD is able to employ on the NWC segment of the Delgany Interceptor.

Constructability discussions were held with MWRD to identify construction methods and means that can accomplish the wet-tap tie-ins. MWRD indicated that the total flows of the Delgany Interceptor can be diverted into a single Delgany Interceptor pipe, allowing one of the pipes to be “dried up”, for limited operational periods (possibly 2 weeks), with the following critical caveats:

- The flow diversions must occur during winter months, when the base flows in the Delgany are at or near their lowest

- The operation of interconnected MWRD wastewater collection facilities must be operating normally to allow MWRD to have full operational capacity in those connected facilities and to possibly further reduce the flows in the Delgany Interceptor
- Extreme weather events that would hamper outdoor construction activities or produce significant inflows into the MWRD collection system would require cancellation or postponement of wet-tap tie-in activities
- The new Delgany Interceptor pipes must be installed, tested, and ready for commissioning prior to any wet-tap tie-in to the existing Delgany Interceptor
- MWRD and construction contractor activities must be closely coordinated, and the construction contractor must provide assurance that all required labor, equipment, materials, and supervision are available on a 24-hour per day, 7 day per week basis while the Delgany Interceptor “dry-up” is occurring. This may include the requirement for arrangements for temporary by-pass pumping of Delgany Interceptor flows.

The existing Delgany infrastructure can be temporarily modified at both the upstream and downstream ends, using pneumatic plugs, mechanical plugs, sand bags, or other methods for temporarily sealing pipe openings, to allow one existing Delgany pipe to be connected to the new Delgany Interceptor pipes while the other Delgany pipe is in operation. The construction contractor would be responsible for accomplishing the temporary seals, with his methods and means subject to review and approval by MWRD and NWCO. Other construction methods that could be used to fast-track the connections, including 24-hour continuous construction, use of high-early strength concrete and/or pre-fabricated structures would also be required or encouraged, as appropriate.

The constructability review of the wet-tap tie-ins to the existing Delgany Infrastructure identified several issues that must be addressed as part of the final design of new Delgany Interceptor pipes (as described above), but it also concluded that the wet-tap tie-ins are feasible and constructible.

3.6 RECOMMENDATIONS

The analyses and evaluations performed herein indicate that the required engineering performance criteria can be satisfied for the alignments that were studied. The limiting factors for the feasibility of the alignments are related to “external” considerations, primarily infrastructure and site use factors that required the elimination of Alignment D and Alignment E from consideration. Alignment A, Alignment B, and Alignment C are acceptable alignments for the Delgany Interceptor. The construction of new Delgany Interceptor pipes along any of the acceptable alignments will extend the service life of the Delgany Interceptor, but the new alignments do not offer significant operational or maintenance advantages over the existing Delgany Interceptor pipes. The final selection of a Delgany Interceptor alignment is interdependent with the analyses and decisions required for the Riverfront Open Space Alternatives described in Section 5 of this Study. A decision on a preferred Riverfront Open Space Alternative along with a coordinated selection of a corresponding alignment for the Delgany Interceptor pipes is required.

4.1 SEWER HEAT RECOVERY PURPOSE

With the recognized value of the potential for thermal energy recovery from the Delgany Interceptors, there is interest in a conjunctive use of sewer heat recovery (SHR) to supply the thermal demands at the redeveloped NWC. SHR is the capture of heat that is intrinsic in municipal wastewater[1], and the utilization of that energy to offset heating and cooling demands. Heat extraction from sewage in the wastewater collection system is an area of interest that has been evolving and has raised interest from both the private and public sectors. At the NWC, SHR would meet the needs not only of the campus, by providing heat for the buildings from a renewable source, but also for Metro Wastewater Reclamation District (MWRD), the wastewater utility which must find a way to reduce the temperature of the effluent released from their nearby wastewater treatment plant. SHR at NWC can potentially help MWRD towards their goal of reducing the effluent temperature by 4°C.

The purpose of this SHR Analysis is to summarize the research, evaluations, and calculations that were completed to identify and screen SHR Alternatives at NWC. The research and analysis tasks included estimating the thermal energy supply in the Delgany Interceptor, quantification of heating and cooling demands, and a detailed review of the relative costs and operational impacts of implementing SHR options. This information was used as input into the SHR screening analysis in order to identify viable heat recovery opportunities for the NWC, and to help establish optimum location(s) for thermal energy recovery.

4.2 SEWER HEAT RECOVERY OBJECTIVES

Under the guiding principle of Embrace an Ethic of Regeneration, the NWC Master Plan has identified net-zero energy as a goal in the redevelopment of the NWC:

> *EER 3.1: Create a "net zero" energy district, prioritizing technical and behavioral strategies to increase efficiency and using on-site renewable energy sources (by 5 years after full build-out)*

The City, CSU and MWRD have expressed interest in partnering on innovative ways to meet the NWC's net-zero energy goals. SHR at the NWC has been identified as an opportunity to facilitate the reduction of sewage temperature in the Delgany Interceptor during the winter season while providing thermal energy as a resource to the NWC. The recovered thermal energy would be used to reduce the use of electricity and natural gas at the NWC for space heating, domestic hot water heating and snow melting for sidewalks and parking areas. The reduction of sewage temperature will help MWRD meets the mandated temperature goals for effluent released into the S Platte River.

There is also interest in using the Delgany Interceptor as a thermal sink and to enable NWC to provide thermal energy input into the Delgany Interceptor to provide cooling during the summer season. The MWRD has indicated that there is capacity in the Delgany Interceptor as a thermal sink in the summer.

[1] [1] Thermal energy found in wastewater collection systems originates from the discharge of hot water from residential, industrial, commercial, and institutional sources. Heat from residential sewage typically originates from activities such as showering, cooking and dishwashing, and the use of laundry machines.

SHR has been identified as a potential strategy to meet the goal of net-zero energy on the basis of available capacity in the Delgany Interceptor to provide thermal energy to meet the heating demands at the NWC, as well as provide capacity for cooling at the NWC.

The supply and demand for thermal energy may vary throughout the year. An opportunity to address this issue is a thermal storage system, which will allow thermal energy to be collected when it is available and used whenever it is needed.

4.3 SEWER HEAT RECOVERY AT NWC

The use of the Delgany Interceptor to meet heating demands will generally require the following major steps:

- Thermal energy extraction from the Delgany Interceptor and conversion to higher-grade heat at a centralized energy center;
- Thermal energy transfer via distribution loop piping (hydronic piping system) to multiple buildings;
- Thermal energy recovery at buildings; and
- Thermal energy distribution throughout the buildings via HVAC systems.

Figure 4-1 illustrates a conceptual diagram of an SHR distribution loop for heating that can eventually serve the entire campus, at full buildout.

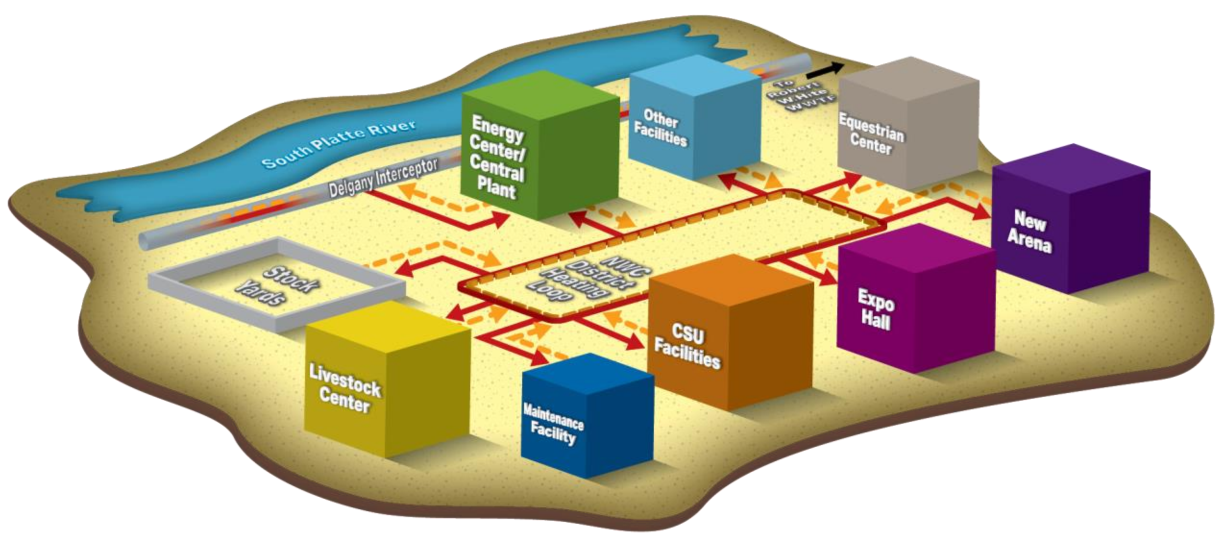


Figure 4-1:
Conceptual SHR Heating Distribution Loop System

The heating distribution loop is a two pipe system: one pipe circulates the high temperature water produced at the energy center (red solid lines) and the other pipe returns cooler water to the energy center (orange dashed line).

Similarly, the use of the Delgany Interceptor to meet cooling demands will generally require the following major steps:

- Thermal energy rejection from building spaces via HVAC systems;
- Thermal energy recovery at buildings;
- Thermal energy collection from multiple buildings and transfer via distribution looping piping; and
- Thermal energy sink via an energy center to the Delgany Interceptor.

Figure 4-2 illustrates the conceptual diagram of SHR for cooling that can eventually serve the entire campus, at full buildout.

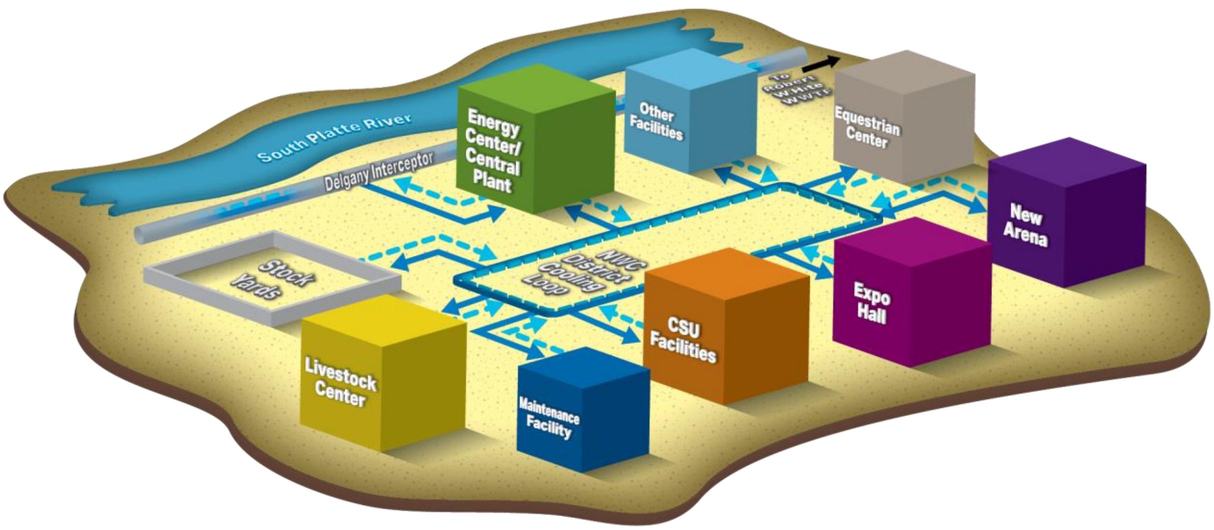


Figure 4-2:
Conceptual SHR Cooling Distribution Loop System

The cooling distribution loop is a two pipe system: one pipe circulates the low temperature water produced at the energy center (blue solid lines) and the other pipe returns warmer water to the energy center (blue dashed line). Additionally, thermal storage could potentially be used as a thermal energy sink for cooling and/or provide a supplementary source for heating. Thermal storage systems typically form a part of a district energy system by taking excess heat not used in a system and placed in a storage medium, and extracted back in to the district energy system when demands exceed supply. Thermal storage is generally included as a means to help maintain a balance between energy supply and demand via peak shaving and to enhance system stability and operational flexibility.

The following sections summarize available SHR technologies potentially suitable for the NWC.

4.4 SEWER HEAT RECOVERY - WASTEWATER

SHR can be implemented using raw wastewater or treated wastewater effluent as the thermal energy source or thermal sink. There are two typical approaches to SHR, sidestream diversion and inline systems, both of which are described below. The use of raw wastewater or wastewater in the collection system pipes that has not yet been treated at the wastewater treatment facility (WWTF), in a sidestream application typically requires screening and solids handling to minimize heat pump fouling. Inline systems can be used in raw wastewater applications to reduce screening and solids handling requirements. One reason to use raw wastewater in lieu of treated effluent is its proximity to the end users of the heat, as WWTF are usually located on the outskirts of municipal regions. However, the available thermal energy may not be as high as at a WWTF.

The use of treated effluent from a WWTF is beneficial where sewage has undergone wastewater treatment and screening and solids handling is upstream of SHR. Furthermore, since a WWTF collects flow from the entire wastewater collection system network, more thermal energy is generally available in the treated effluent. However, since thermal demands may not be in the vicinity of the WWTF, heat recovery from treated effluent typically requires more distribution piping to deliver thermal energy to end users. A general comparison of advantages and disadvantages of SHR for raw sewage and WWTF effluent is presented in Table 4-3.

Table 4-1:
Raw Sewage vs Treated Effluent

Energy Source	Advantages	Disadvantages
Collection System (Raw Sewage)	- Accessible in many locations	- Solids handling, bio-fouling - Seasonal and diurnal variations
WWTP (Treated Effluent)	- Simple equipment - Receiving water can benefit from decreased effluent temperature	- WWTP typically not located close to users (prohibitive distribution system costs)

This report will focus on the use of raw sewage flowing through the Delgany Interceptor as the thermal energy source for heating and thermal sink for cooling. The MWRD also has indicated a potential option to supply thermal energy to the NWC from treated effluent at the Robert W. Hite WWTF but this is being studied by MWRD outside of the scope of this study.

4.5 SEWER HEAT RECOVERY SYSTEMS

There are a small number of commercially available heat recovery technologies for decentralized installation in a sewerage system. The technologies address the two main SHR categories: In-Line and Sidestream systems.

4.5.1 In-Line SHR Systems

An In-Line heat recovery system utilizes a heat exchanger within the sewer pipe; wastewater is not removed from the sewer with these technologies. The systems can be installed into existing sewer pipes as a heat exchange liner, or installed into new infrastructure as heat exchangers integrated into the pipes.

Heat exchange liner systems will reduce the cross sectional area in the pipe available for conveying flow by 2 – 15%, depending on the type of liner and size of the pipe. The liners are designed to have no reduction of flow velocity in the pipes and are streamlined to minimize the accumulation of grit and rags. A small pump is required to circulate the heat exchange water, and an external heat pump is required to complete the system. As the technology is relatively new, the long-term use and service requirements of the liner systems are fairly unknown. Two examples of heat exchange liner technologies that are commercially available are shown in Figure 4-3 and Figure 4-4.

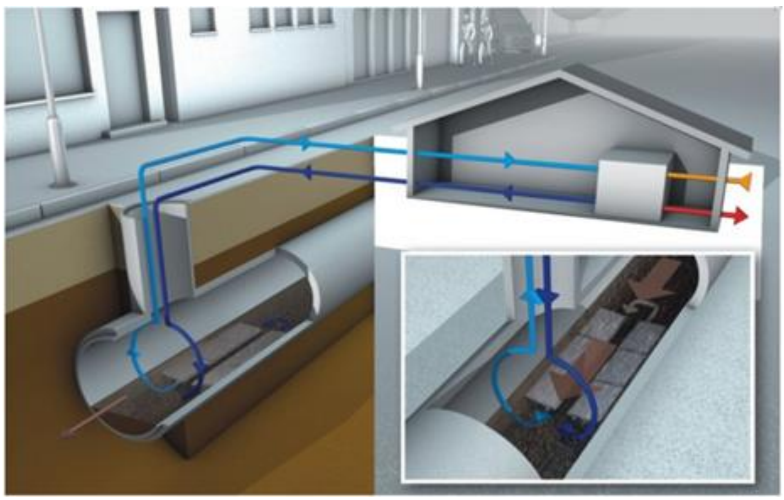


Figure 4-3:
Design Sketch of Tube Win System (Huber Technology)

Figure 4-4:
Therm-Liner B Variant, Half-Shell (UHRIG)

Heat exchangers that are integrated into the sewer pipes will not reduce the flow area; however, the wall of the pipe will be thicker than a conventional pipe. An example of this type of heat recovery technology is shown in Figure 4-5.

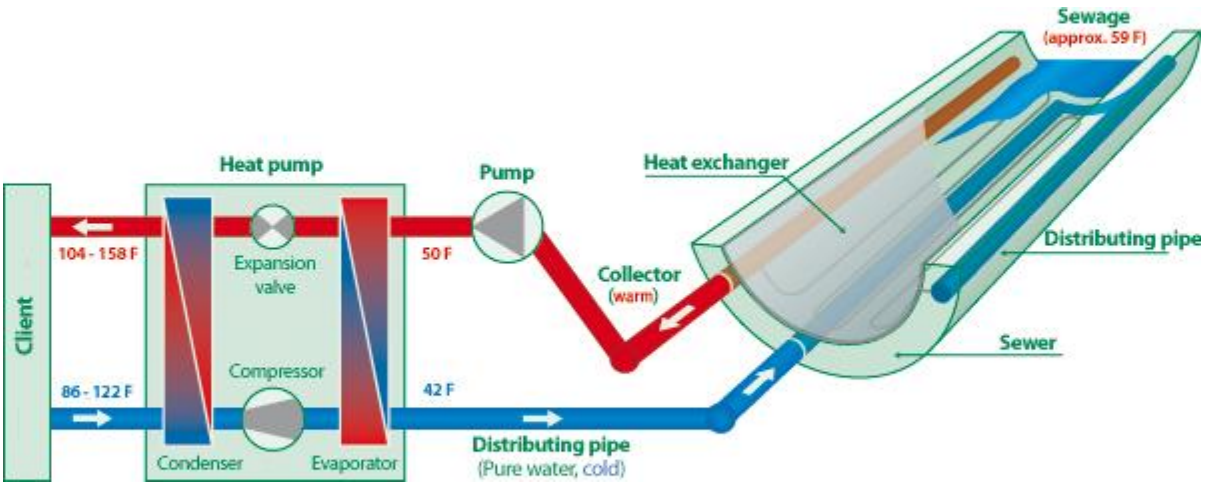


Figure 4-5:
Rabtherm Energy Systems Integrated Heat Exchanger

The technology selection considerations for In-Line SHR systems include:

- Limited thermal capacity, typically still requires an external heat pump
- Larger overall footprint
- Advantageous for new sewer construction, major sewer rehabilitation or relocation
- Periodic maintenance of the heat exchanger is required (less frequent than for a heat pump)
- No sewage diversion, limited potential for clogging of equipment, and no screening or solids handling is required
- Odor control requirements typical for a collection system

Refer to the case studies listed in **Appendix C** for examples of inline SHR systems.

4.5.2 Sidestream Systems

Sidestream heat recovery systems feature a heat exchanger that is external to the wastewater flow. This concept involves diverting the wastewater from the sewer to an adjacent wet well, where it is screened and directed through a heat exchanger. Within the heat exchanger, the screened wastewater transfers its thermal energy through stainless steel pipes to the clean water. The screened wastewater is cooled by approximately 5°C in the heat exchange process and is returned to the sewer, along with the screenings. A conceptual Sidestream SHR system is presented in Figure 4-6.

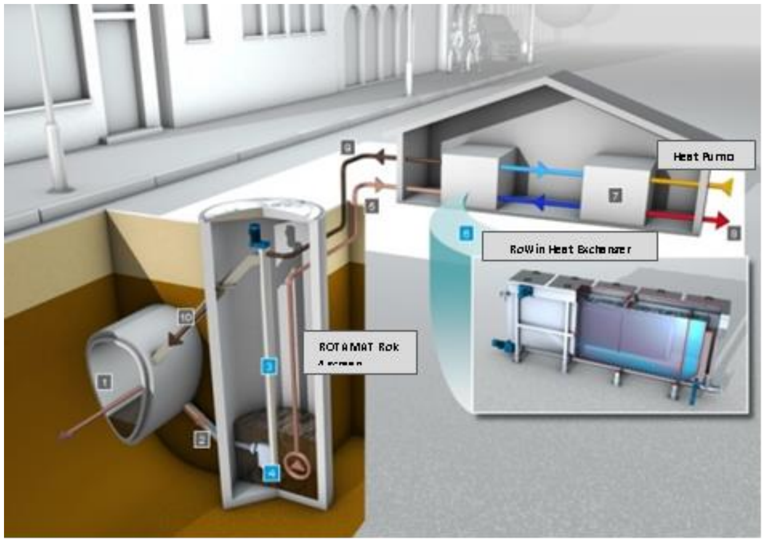


Figure 4-6:
Systems Concept for Heat Recovery with External Heat Exchanger (HUBER ThermWin®)

Sidestream SHR vendor packages are generally supplied as modular units and selected based on the available wastewater flowrates. For example, the SHARC 880 can process up to 1,500 gpm of untreated wastewater and provide approximately 1,000 kW of energy. Multiple units can be installed to utilize higher flows and increase the sewer heat energy capacity. Due to the inherent properties of wastewater, a biofilm will form on the heat transfer surfaces over time and therefore it is imperative that preventative cleaning is performed to ensure the maximum heat transfer capacity is maintained.

The technology selection considerations for Sidestream SHR systems include:

- Larger thermal capacity compared to an inline heat exchanger
- Smaller overall footprint in comparison to an In-Line heat exchanger system
- Advantageous for tie-ins to existing sewer infrastructure
- Regular maintenance of heat pump equipment is required
- Screening and solids handling is required
- Increased risk of odors in comparison to an inline heat exchanger system, requiring odor control to mitigate

Refer to the case studies listed in **Appendix C** for examples of Sidestream SHR systems. A brief comparison of design considerations for In-Line SHR systems and Sidestream SHR systems is presented in Table 4-2.

Table 4-2:
Inline vs Sidestream SHR

	In-line SHR	Sidestream SHR
Description	Heat exchange performed within gravity sewer pipe	Wastewater removed from sewer to perform heat exchange
Capacity	Limited capacity (<1 MW)	Large heating capacity possible
External heat pump required?	Yes	Yes
Footprint	Larger overall footprint due to length of HEX pipe required; smaller out-of-sewer footprint	Smaller overall footprint
Sewage diversion required?	No	Yes
Solids handling required?	No	Yes
Odors	Typical of collection system	Increased risk of odors due to solids handling
Maintenance	Bio-fouling may be an issue	Frequent and potentially complex maintenance

4.6 DISTRIBUTION LOOPS

Although heat energy extraction can be achieved directly from a sewer to individual buildings, sewage heat recovery is highly compatible with district energy systems and is a cost-effective means of delivering thermal energy to multiple buildings from a centralized energy source. Distribution loops are used to supply thermal energy to multiple buildings for heating following the extraction of thermal energy from the source at the energy center. Similarly, distribution loops can also be used to collect and convey the heat rejected from HVAC systems for cooling from multiple buildings back to the Delgany Interceptor via the energy center. Although it may be possible to use a single loop in a district energy sharing system for both heating and cooling, separate heating and cooling loops are typically used to minimize operational complexity and to optimize the efficiency of both heating and cooling systems.

District heating requires a hot water supply and hot water return pipe for the distribution loop. Similarly, district cooling requires a chilled water supply and chilled water return pipe for the distribution loop. Thus, if both heating and cooling are considered at the NWC, there will be a requirement for four pipes and will require space allocation in the utility trenches and/or corridors to allow the piping to be looped around the NWC.

Distribution of hot water or chilled water requires the use of pumps to circulate the liquid medium, typically water or a glycol-water mixture, through the distribution loops.

Furthermore, distribution loops are generally categorized as either ambient temperature loops or high temperature loops. The following sections describe each type of distribution loop.

4.6.1 Ambient Temperature Loops

Ambient temperature loops typically circulate fluid (water or water-glycol mixture) up to 77 ^{o}F (25 ^{o}C) through piping to convey low-grade thermal energy to each building connected to the loop. The use of an ambient temperature loop will require a heat exchanger at the energy center or central plant as illustrated in Figure 4-7 below.

Ambient temperature distribution loops require the placement of heat pumps in individual buildings to upgrade to higher-grade heat that is suitable for use in the hydronic system within the building for space heating and domestic hot water heating.

One of the benefits of an ambient temperature loop is the lower potential for heat loss through the distribution piping due to a lower thermal gradient caused by the difference in temperature between the fluid in the loop piping and the ambient ground temperature. However, one of the main challenges of an ambient temperature loop is the distributed nature of the heat pump equipment required in each building, which results in significantly more complex operation and maintenance activities to manage each piece of equipment. Furthermore, backup boilers using natural gas would be required in each building to supply heat if the heat pump is offline.

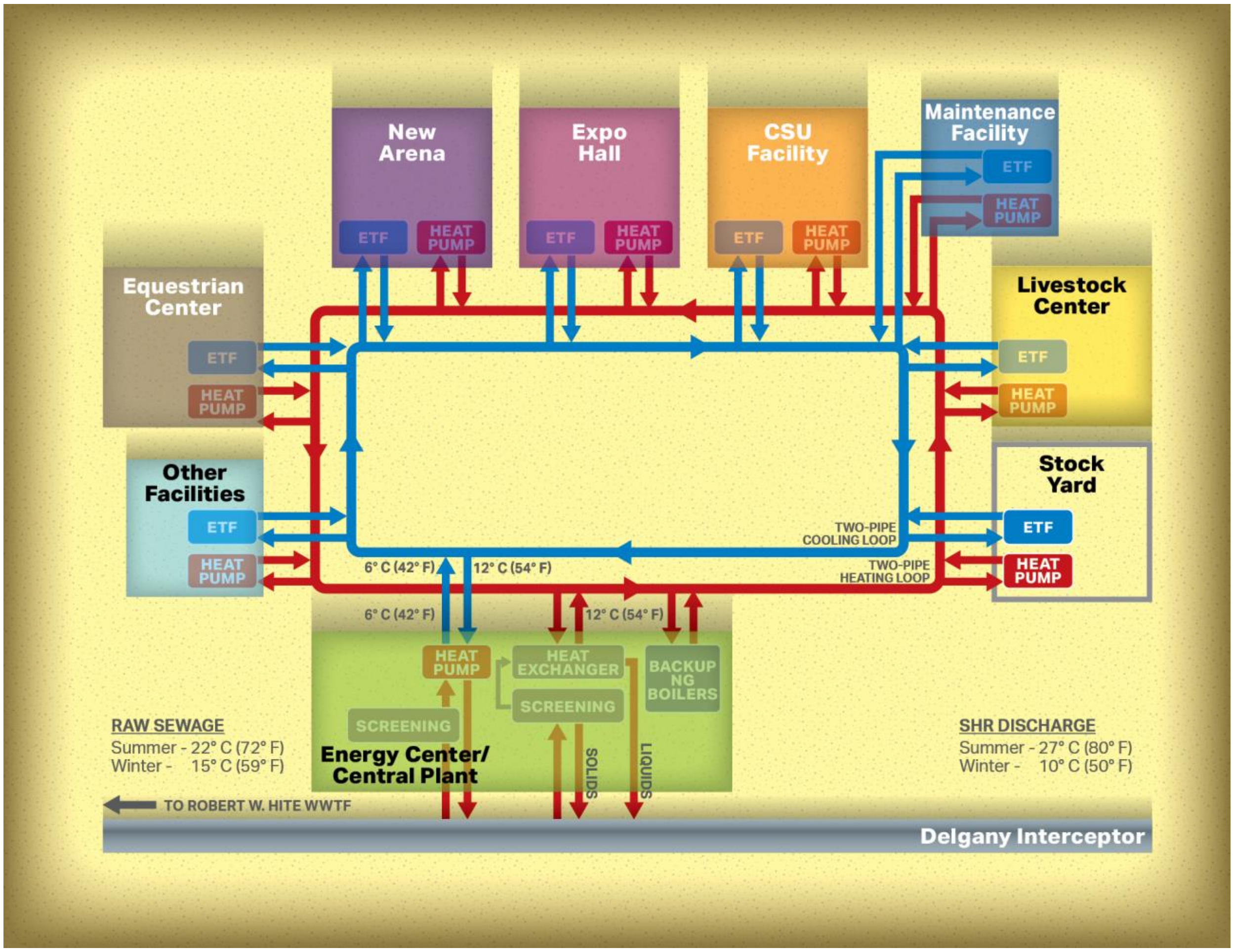


Figure 4-7:
SHR Ambient Temperature Distribution Loop

An example of an ambient temperature distribution loop can be found at the Cheakamus Crossing DES system in Whistler, BC (formerly the Whistler Athletes' Village District Energy System).

4.6.2 High Temperature Loops

Similar to ambient temperature loops, high temperature loops also circulate fluid (water or water-glycol mixture) through piping with the difference being that a high temperature loop circulates high-grade heat up to 180 °F (82 °C) from a heat pump to individual buildings. The efficiency of the SHR system (particularly the heat pumps) using a high temperature loop is highly dependent on the return temperature back to the heat pump.

One of the benefits of a high temperature loop is the reduced operation and maintenance complexity due to the centralized location of the heat pump and backup boiler located in the energy center. The challenge of using a high temperature loop is that the higher thermal gradient caused by the difference in temperature between the fluid in the loop piping and the ambient ground temperature, which requires mitigation via the use of insulated piping that carries a higher capital cost in comparison to an ambient temperature loop.

[Add comparison chart/table of Ambient vs High Temperature Loops]

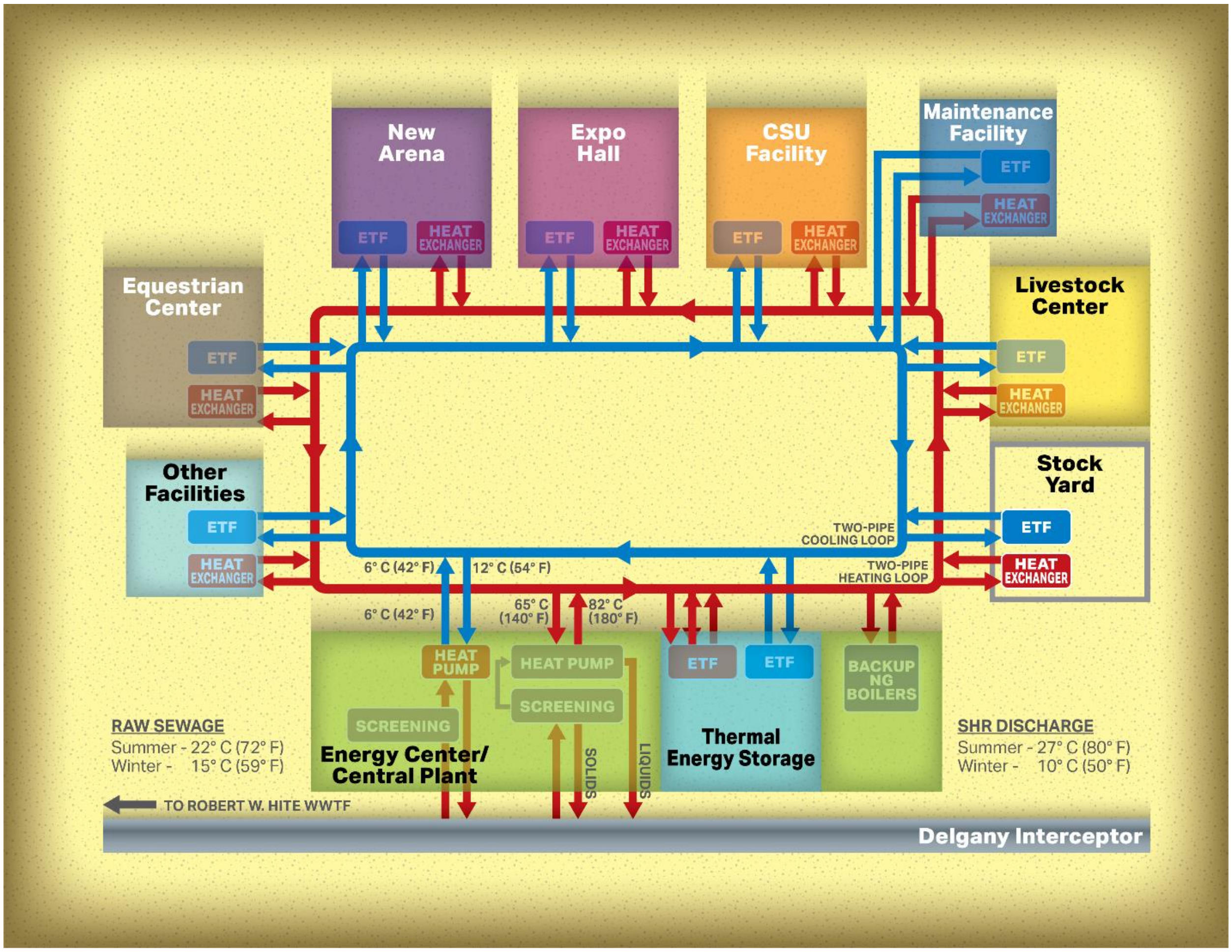


Figure 4-8:
SHR High Temperature Distribution Loop

An example of a high temperature distribution loop can be found at the Southeast False Creek Neighborhood Energy Utility in Vancouver, BC.

4.7 ENERGY TRANSFER FACILITIES

ETFs are located at each individual building that connects to the distribution loop and draws heat from the distribution loop for heating and transfers heat from rejected from buildings into the distribution loop in cooling mode. A heating distribution loop provides space heating and domestic hot water heating via hydronic heating systems within each building to deliver heat to conditioned spaces. For cooling, heat rejected from conditioned spaces is transferred back to the ETF and into the cooling distribution loop.

When the SHR system makes use of a high temperature distribution loop, the ETF is essentially a heat exchanger that provides passive heat transfer from the distribution loop to the building HVAC system. If an ambient temperature loop is used, the ETF requires a heat pump and backup natural gas boilers to upgrade the heat to a higher temperature suitable for space heating and domestic hot water heating.

4.8 THERMAL STORAGE

Thermal storage involves the use of piping and heat exchangers to convey thermal energy into the ground that can be extracted at a later time. Thermal storage systems are typically borehole systems using borehole fields of U-tube or coaxial heat exchangers to store thermal energy in soil/rock. Some thermal storage systems may also use a local aquifer for thermal energy storage but such systems are less common due to the potential to cause undesirable influences on local hydrogeology.

The daily and seasonal peak SHR thermal energy supply available in the Delgany Interceptor generally does not coincide with peak thermal demands at the NWC. Refer to Figure 4-9 for an example illustrating the differences between the diurnal thermal energy supply and demand profiles.

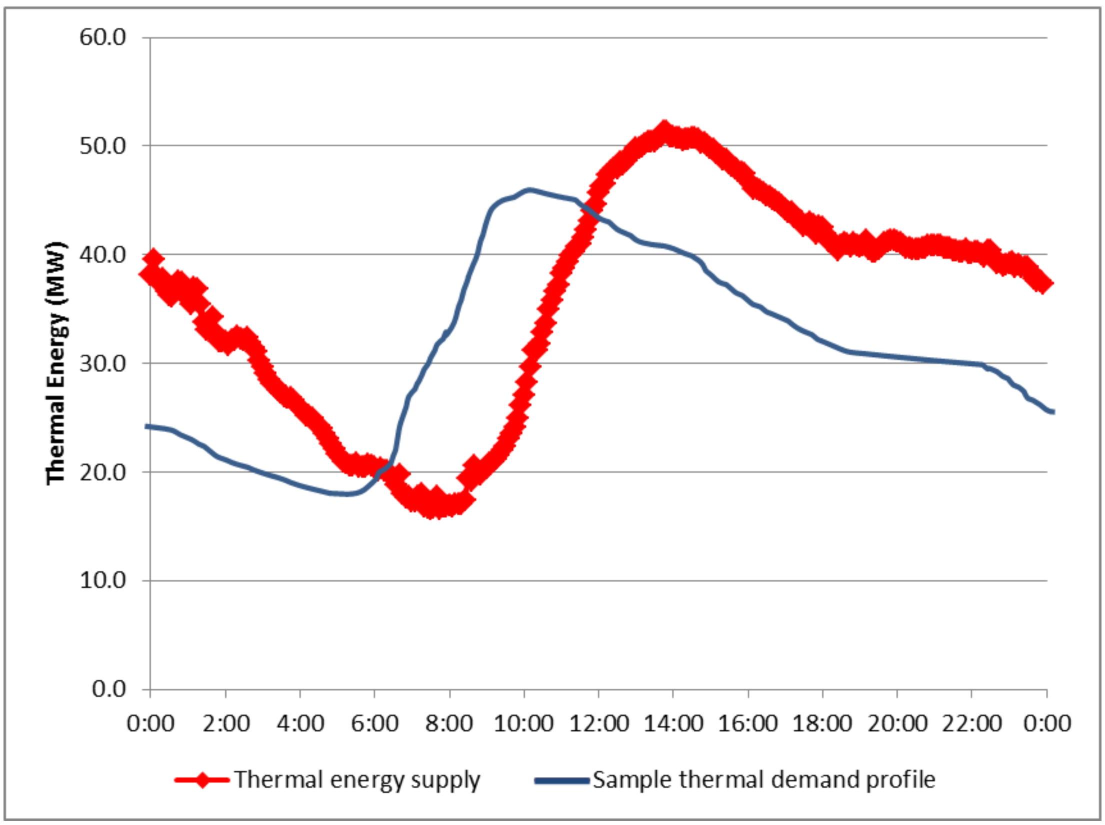


Figure 4-9:
Example of Diurnal Thermal Energy Supply and Demand Profiles

The benefits of thermal storage to further offsetting the consumption of electricity and natural gas include:

- Balancing thermal demands as required on a daily basis (i.e. supplementing thermal energy from SHR during low flows or sewage temperature in the Interceptor, and/or peak daily thermal demands due to cold weather).

- Potentially storing heat in the winter during periods of low heating demand to supplement the thermal energy provided by SHR during periods of peak heating demand.
- Storing heat rejected from cooling buildings in the summer for use when heating is required.

Seasonal thermal storage could potentially enable the NWC to extract thermal energy from the Delgany Interceptor in the summer, store the thermal energy in the ground, and extract the thermal energy as required to meet heating demands. Similarly, seasonal thermal storage could enable the NWC to store thermal energy extracted from cooling buildings for use in the winter to supplement thermal energy extracted via SHR. However, it is important to note that thermal storage is not integral to the SHR system (i.e. a SHR system does not require a thermal storage system to operate) and a SHR system can be operated without the use of thermal storage. Thermal storage is an innovative concept but with limited examples in literature and there are no known thermal storage systems combined with a SHR system.

To determine from a technical perspective whether thermal storage is feasible for the NWC, it is critical to understand the local geology at the NWC site in order to assess the thermal properties of the ground, as well as the presence, depth and flow of groundwater. Modeling and test boreholes are required to determine the optimum borehole size, depth, location at NWC, and arrangement in the field. Geotechnical analysis is outside of the scope of this Study and it is recommended that if thermal storage is of interest, then a detailed geotechnical analysis will need to be conducted to determine the feasibility of thermal storage. If thermal storage is technically feasible at the NWC, it is also important to conduct a cost-benefit analysis to determine the optimum sizing of a thermal storage system.

4.9 OPERATIONAL IMPACTS

4.9.1 Systems/Design considerations

The thermal energy supply available for the NWC is dependent on both the flow rate and temperature of the raw sewage flowing through the Delgany Interceptor. If there is flow diversion from the Delgany Interceptor, the efficiency of the SHR system may decrease or the SHR system may shut down completely. Thus it is important to maintain sufficient flow through the Delgany Interceptor, and close coordination with MWRD will be required if there is a need for an operational flow diversion from the Delgany Interceptor. Based on the historical flow data provided by MWRD the flow in each of the Delgany Interceptors can fluctuate; however, the combined flowrate is relatively constant.

The use of SHR in a sidestream application requires the use of screening and solids handing processes to separate the raw sewage liquid from solids. Screened solids that are separated from the raw sewage are typically returned to the sewer. Raw sewage liquid is also returned to the sewer once the thermal energy has been extracted by the heat pump. Where screening and solids handling processes are required, there is the potential for odor generation. Thus, it is important to mitigate odor concerns proactively and to ensure that the SHR system does not create an odor issue by including odor control systems in the design and implementation of an SHR system. MWRD is aware of the need for odor mitigation on the existing Delgany Interceptor pipes, and is currently studying and planning to address odor control on a systemwide basis, including odor control for SHR facilities if necessary. It has been confirmed with MWRD that the Delgany SHR facilities at NWC will be included in their systemwide odor control program.

4.9.2 Best Practices

Based on the experience at SEFC, the average flow rate of raw sewage for thermal extraction via SHR is between 475 - 635 gallons per minute (gpm)/MW installed capacity. Raw sewage is brought in to a wet well for equalization and the screened liquid stream passes through the heat pump. The screened solids are returned to the sewer. The screened liquid stream is also returned to the sewer once thermal energy extraction has occurred.

One of the key variables in the operation of an SHR system is the temperature of the incoming raw sewage. Rapid temperature drops can result in SHR heat pump shutdown. This issue is more commonly observed in collection systems that have a relatively large inflow and infiltration component, combined with wet weather events during periods of cold weather that tends to reduce the temperature of the sewage during wet weather events.

The use of SHR requires a backup source of thermal energy supply in the event of a shutdown of the SHR system due to insufficient raw sewage flow or low temperature. Typically, the use of SHR includes the provision for natural gas boilers that are used as a backup system, and also to meet the peak thermal demands of the system (referred to as trimming). Some existing SHR systems can satisfy 95% of the annual thermal consumption by sizing SHR systems to meet 60-70% of the peak system demand, with the balance of the peak demand being met by the natural gas boilers (which can be effectively achieved by sizing the natural gas boilers for full system redundancy and providing the benefits of trimming as well as full backup in case of a heat pump shutdown). The unique operating demands of the NWC (as compared to existing SHR systems), including short but intense heating and cooling demands in the Winter and Summer require that detailed analysis of the heating and cooling systems are required as part of the system final designs to determine the preferred capacity of the SHR system and the backup heating and cooling systems.

Within the distribution system, leak detection and mitigation is an important feature in the distribution piping for a SHR system since the presence of leaks will have a direct impact on the thermal energy delivered to heat building spaces and on the heat rejection potential from cooling building spaces.

The return temperature from a distribution loop back to the SHR heat pump is an important consideration. To maintain system efficiencies in a high temperature distribution loop, the design return temperature back to the heat pump should be at or around 149°F (65°C).

One of the key variables in the operation of an SHR system is the temperature of the incoming raw sewage. Rapid temperature drops can result in SHR heat pump shutdown.

<u>Operation and Maintenance</u>

- The use of district heating and/or cooling has the benefit of reducing the level of effort for operations and maintenance that would typically be required for in-building HVAC equipment.
- Close monitoring of temperature and flow in the Delgany Interceptor, as well as in the SHR heat pumps, distribution piping and ETFs is an important feature for monitoring the SHR system and to obtain data regarding the efficiency of the SHR system.
- Regular preventative maintenance of the heat pumps is required to reduce the effects of fouling that can accumulate within the heat pump and reduce system performance. Operational

strategies such as regular reversal of flow direction and/or backwashing can be effective in reducing the effects of fouling.

- Property and liability insurance costs may be reduced with the elimination of boilers, chillers, pumps, and electrical switch gear that would typically be located in building, since the risk of a fire or accident would be reduced.

4.10 ENVIRONMENTAL IMPACTS

The use of SHR can provide positive benefits to the environment, usually with minimal adverse impacts. Potential benefits to the environments include:

- Reducing sewage temperature which can translate into decreased wastewater effluent temperature discharged to the receiving waters (a benefit specifically to the South Platte River)
- Reducing natural gas and electricity use via a renewable energy source
- Reducing greenhouse gas emissions
- Lowering NOx, VOC's and other combustion by-products from burning coal or natural gas
- Using hot-water radiant heating which is typically highly efficient
- Using distribution loops, which are adaptable and have flexibility to accommodate different thermal energy sources

Possible adverse SHR impacts, such as noise, odor, and waste solids, are typically eliminated or mitigated through appropriate SHR system design.

4.11 CONSTRUCTABILITY

There is flexibility in both the location of the energy extraction point along the existing Delgany Interceptor and among the various proposed alignments, as well as in the location of the SHR energy center/central plant, given that the NWC is immediately adjacent to the existing Interceptor pipes. Typically, SHR locations within 2,300 - 3,300 ft of the thermal supply are viable, but proximity requirements are generally dependent on the specific technical and financial considerations for each project.

The phasing of the SHR heat pump and ancillary equipment can be aligned with the phasing of the NWC development since heat pump and chiller technologies are modular. The distribution loop piping alignment would need to be consistent with each development phase and expanded to service new phases as each phase connects to the distribution loop. The design of the distribution loop would need to include constraints regarding sizing so that the system is capable of meeting the demands of each phase while at the same time taking into consideration the need to expand the system to meet future heating and cooling demands. New buildings connecting to the SHR system would require the ETF to either tie-in at existing locations within the loop or require an extension of the loop.

Individual buildings would require HVAC infrastructure compatible with the SHR system, such as the use of hydronic systems for heating and cooling in the building (as opposed to using electric baseboards or in-building forced air systems). Hydronic systems are standard, proven methods in building services.

Hydronic systems are considered to be quieter, cleaner, and more comfortable (no hot or cold drafts) than a forced air system, and they are typically much more energy efficient than electric baseboards.

SHR would require a central energy plant to house heat pumps, chillers, and backup equipment. The footprint of the central energy plant should provide sufficient space for operating and maintaining the heat pump and chiller equipment.

4.12 CONCEPTUAL DESIGN

The conceptual design of a SHR facility for the NWC is summarized in Table 4-3.

Table 4-3:
SHR Components

SHR Component	Assumptions
Tie-ins to the Delgany interceptor	**2 x 24" tie-ins for flow to/from SHR energy center**
Raw sewage conveyance	**2 x submersible raw sewage pumps in a wet well, capable of conveying 12,680 - 14,270 GPM to the SHR energy center screening system**
Screening	**2 x 2 mm bar screens each capable of screening 6,340 - 7,930 GPM of raw sewage**
Space required - SHR heat pumps in Energy Center	**50 ft x 50 ft x 8 ft tall**
SHR heat pumps (heating)	**2.5 MWt**
Backup boilers and chillers[2]	**2 x 13.5 MWt**
Distribution pumps	**VFD driven (1 duty, 1 standby for heating loop, and 1 duty, 1 standby for cooling loop) each capable of circulating approximately 4,750 GPM of water.**
Distribution loops (heating and cooling)	**Four-pipe system (hot water supply, hot water return, chilled water supply, and chilled water return)** **16" diameter thin walled steel piping with polyurethane foam insulation, HDPE jacket, and integrated leak detection. Approximate length 2000 – 3000 m. Assumed distribution loop pressure drop of 250 Pa/m**

[2] Boilers and chillers form a part of the district system independent of whether SHR is implemented. This study focuses on the SHR heat pumps and thermal energy supply from sewage and thus boilers and chillers are excluded from the scope of this study.

SHR Component	Assumptions
Thermal Storage[3]	**Excluded**

The thermal supply, or available heat energy, of a sewer system is a function of the mass flowrate of the wastewater and the mean temperature difference between the hot and cold fluids before and after heat transfer. Historical wastewater flow data from 2012 – 2016 was provided for the dual Delgany Interceptors, and the total combined flow has been used in this analysis. Sewage temperatures in the Interceptors were measured at manholes DG045 and DGC005A from December 2015 to May 2016 at 30 minute intervals, which provided information regarding the conditions during the winter months. The design parameters that were used to estimate the conceptual thermal supply of wastewater in the Delgany Interceptors are summarized in Table 4-4.

Table 4-4:
Conceptual Design Parameters for Delgany Interceptors

Parameter	Units	Value
Wastewater Flow (Winter)[1]	L/s	1,200 – 1,300
	MGD	27 – 30
Wastewater Flow (Summer)[1]	L/s	1,300 – 1,400
	MGD	30 – 32
Wastewater Temperature	°C	17 – 22
Wastewater Density[2]	kg/L^3	1.0
Specific Heat Capacity[2]	kJ/kg-ºC	4.184

Notes: 1. 75th percentile summer and winter flow rates based on analysis of Delgany flow data from 2012-2016.
2. Assumed raw sewage density and specific heat capacity are the same as for clean water

4.13 BASELINE

The assumptions carried in this study to estimate thermal supply and demand are based on the following:

[3] Thermal storage with SHR is an uncommon application with no known examples where this technology has been implemented. This system is referenced in the table to provide a conceptual illustration of the approximate scope/extent of the system and has not been included in the thermal supply and demand analysis. Design work is required to confirm whether thermal storage is applicable to the SHR system contemplated for the NWC.

Table 4-5:
Baseline - Heating

Category	Baseline
Wastewater medium	**Raw sewage from the Delgany Interceptor**
Wastewater thermal gradient	**ΔT = 5 °C**
SHR system	**Sidestream SHR with screening, heat pumps in a central heating plant, high temperature distribution loop using water, heat exchangers at buildings, and backup boilers using natural gas**
Thermal storage	**Excluded**
COP	**3.0**
NWC heating demands	**Refer to Table 4-9**

Table 4-6:
Baseline – Cooling

Category	Baseline
Wastewater medium	**Raw sewage from the Delgany Interceptor**
Wastewater thermal gradient	**ΔT = 5 °C**
SHR system	**Heat exchangers at buildings, high temperature distribution loop using water, central cooling plant with heat pumps and backup chillers, and sidestream SHR with screening**
Thermal storage	**Excluded**
COP	**4.0 (Chillers)** **3.0 (Heat pumps)**
NWC cooling demands	**Refer to Table 4-10**

The heating and cooling potential of the Delgany Interceptor is discussed in the following sections.

4.14 HEATING POTENTIAL

The heating potential of the raw sewage in the Delgany Interceptor was estimated based on the assumption that raw sewage is screened, and heat is extracted from the liquid portion of the raw sewage passing through a heat pump. Applying the steady-state energy equation, the thermal capacity was estimated and is summarized in Table 4-7.

Table 4-7:
Conceptual Heating Potential of Delgany Interceptors

Parameter	Units	Value
Heat Pump COP	-	3.0
SHR Raw Sewage ΔT	°C	5.0
Sewage Heat Energy Capacity	MWt	25 – 27
	MMBTU/hr	85 – 92
Total Available Heating Capacity at NWC[1]	MWt	37 – 40
	MMBTU/hr	128 – 139

Notes: 1. Incorporates heat pump COP

4.15 COOLING POTENTIAL

Similar to the estimate of the heating potential, the cooling potential was estimated based on the assumed maximum rise in raw sewage temperature in the Delgany Interceptor during the summer months. In a district cooling loop, either a chiller system or heat pump could be used. Use of heat pumps was assumed since typically it carries a lower COP than for chillers and represents a more conservative assumption for estimating the available cooling capacity in the Delgany Interceptor.

Table 4-8:
Conceptual Cooling Potential of Delgany Interceptors

Parameter	Units	Value
Heat Pump COP	-	3.0
SHR Raw Sewage ΔT	°C	5.0
Sewage Cooling Capacity	MWt	27 – 30
	MMBTU/hr	92 – 102
Total Available Cooling Capacity at NWC[1]	MWt	40 – 45
	MMBTU/hr	139 – 153

Notes: 1. Incorporates heat pump COP

4.16 HEATING DEMAND

Heating demands for individual buildings will be strongly influenced by factors such as the building use, occupancy, climate, building design, and building construction. For the purpose of conducting a screening level assessment for using the Delgany Interceptor as a heat source, the unit rate heating demands assumed for this study are summarized in Table 4-9.

Table 4-9:
Unit Rates – Space Heating and Domestic Hot Water Heating

Building Type/Category	Peak Unit Heating Rate (W/ft^2) [1]	Annual Space Heating and Water Heating EUI (kWh/ft^2/year) [2]
Public Assembly (Stadium, Arena, Exhibition Hall)	8.4	14.9
Warehouse (assume including barns)	2.8	5.6
Office	5.1	10.2
Commercial	5.1	10.2
Sidewalks/outdoor parking (snow melting)	23.2	18.6

Notes: *1. Rule-of-thumb values. Literature data not available for specific building types/categories proposed for the NWC. Values are highly dependent on building design and occupancy/use.*

2. EUIs from US DOE Buildings Energy Data Book (2003)

Peak unit heating rates and EUIs applicable for each building in the NWC development should be confirmed and refined during the detailed design and implementation phases of the project.

4.17 COOLING DEMAND

Similar to the estimate for heating demand, cooling demands for individual buildings will be strongly influenced by factors such as the building use, occupancy, climate, building design and building construction. For the purpose of conducting a screening level assessment for using the Delgany Interceptor as a heat sink, the unit rate cooling demands assumed in this study have been summarized in Table 4-10.

Table 4-10:
Unit Rates – Cooling and Ventilation

Building Type/Category	Peak Unit Cooling Rate (W/ft2) 1	Annual Cooling and Ventilation EUI (kWh/ft2) 2
Public Assembly (Stadium, Arena, Exhibition Hall)	0.6	7.4
Warehouse (assume including barns)	0.4	1.1
Office	0.7	4.1
Commercial	0.7	4.1

Notes: 1. Unit-area cooling load values from ASHRAE District Cooling Guide (2013).

2. EUIs from US DOE Buildings Energy Data Book (2003).

Peak unit cooling rates and EUIs applicable for each building in the NWC development should be confirmed and refined during the detailed design and implementation phases of the project.

4.18 DEMAND FORECAST

The heating and cooling demand forecast based on the development phasing, usage, and assumed occupancy at the NWC is summarized in Table 4-11 and 4-12.

Table 4-11:
Estimated Building Heating Demands

Facility	Area/Space	Building Type	Floor Area (ft^2)	Floor Area (m^2)	NWC Development Phase	Development Year	Peak Heating Unit Rate (W/ft^2)	EUI - Space Heating and Water Heating (kWh/ft^2)	Peak Demand (MW)	Annual Demand (kWh/yr)
NWC DEVELOPMENT PHASE 1 & 2										
Stock Yard Show and Auction Arenas	Stock Yard Show Arena	Stadium/Arena	20,100	1,867	1	2018	8.4	14.9	0.2	70,000
	Auction Arena	Stadium/Arena	15,000	1,394	1	2018	8.4	14.9	0.1	50,000
Wash Rack building	Wash Rack Building	Warehouse	7,680	714	1	2018	2.8	5.6	0.0	50,000
Water Resource Center	Water Resource Center	Office	150,000	13,936	1	2018	5.1	10.2	0.8	2,400,000
Livestock	5,000 seat Livestock Arena	Stadium/Arena	130,240	12,100	2	2020	8.4	14.9	1.1	690,000
	Tractor space	Warehouse	1,500	139	2	2020	2.8	5.6	0.0	1,000
	Suites	Commercial	4,000	372	2	2020	5.1	10.2	0.0	3,000
	Livestock Hall	Warehouse	231,500	21,508	2	2020	2.8	5.6	0.6	410,000
	Hall Auction Arena	Stadium/Arena	9,550	887	2	2020	8.4	14.9	0.1	50,000
Equestrian	Horsebarn	Warehouse	220,000	20,439	2	2020	2.8	5.6	0.6	390,000
	Equestrian Events Center	Stadium/Arena	100,500	9,337	2	2020	8.4	14.9	0.8	1,260,000
	Exhibition space	Exhibition Hall	3,500	325	2	2020	8.4	14.9	0.0	40,000
	Tractor space	Warehouse	1,500	139	2	2020	2.8	5.6	0.0	1,000
	Suites	Commercial	4,000	372	2	2020	5.1	10.2	0.0	30,000
	Equestrian Arena	Stadium/Arena	86,500	8,036	2	2020	8.4	14.9	0.7	2,260,000
	Covered Indoor Warm Up Area/ Paddocks	Warehouse	48,000	4,459	2	2020	2.8	5.6	0.1	200,000
	Equine Sports Medicine Facility	Commercial	78,664	7,308	2	2020	5.1	10.2	0.4	1,250,000
NWSS Maintenance and Operations Building	NWSS Maintenance and Operations Building	Office	44,000	4,088	2	2020	5.1	10.2	0.2	700,000
NWC DEVELOPMENT PHASES 1 & 2 ANNUAL DEMAND SUBTOTAL:										**9,855,000**
Stock Yard Show and Auction Arenas	Stock Yard Pens	Snowmelt system	836,100	77,678	1	2018	23.2	18.6	19.4	7,340,000
	Livestock Center Plaza, Lower Plaza, Equestrian Center Plaza (assume 10% sidewalk coverage)	Snowmelt system	30,056	2,792	1	2018	23.2	18.6	0.7	260,000
NWC DEVELOPMENT PHASES 1 & 2 ANNUAL DEMAND (WITH SNOWMELT) SUBTOTAL:										**17,455,000**
NWC DEVELOPMENT PHASES 3 - 6										
1909 Arena	1909 Arena	Stadium/Arena	106,000	9,848	3	2022	8.4	15	0.9	1,940,000
Expo Hall	Exhibition space	Exhibition Hall	430,000	39,949	4	2024	8.4	15	3.6	5,650,000
	Ballroom	Commercial	25,000	2,323	4	2024	5.1	10	0.1	200,000
	Cafeteria	Commercial	5,000	465	4	2024	5.1	10	0.0	40,000
Arena	10,000 seat arena	Stadium/Arena	212,000	19,696	5	2027	8.4	15	1.8	3,150,000
	Holding area	Warehouse	25,000	2,323	5	2027	2.8	6	0.1	170,000
	Suites, locker rooms, tractor storage, artist rooms, restaurant, ice making, retail, box office, administrative offices	Commercial	58,700	5,454	5	2027	5.1	10	0.3	730,000
CSU Facility	3-story building (all program areas)	Office	155,735	14,469	6	2030	5.1	10	0.8	2,480,000
NWC DEVELOPMENT PHASES 3 - 6 ANNUAL DEMAND SUBTOTAL:										**14,360,000**

Facility	Area/Space	Building Type	Floor Area (ft^2)	Floor Area (m^2)	NWC Development Phase	Development Year	Peak Heating Unit Rate (W/ft^2)	EUI - Space Heating and Water Heating (kWh/ft^2)	Peak Demand (MW)	Annual Demand (kWh/yr)
									TOTAL NWC DEVELOPMENT ANNUAL DEMAND, ALL PHASES:	**24,215,000**
									TOTAL NWC DEVELOPMENT ANNUAL DEMAND, ALL PHASES WITH SNOWMELT:	**31,815,000**

Notes: *1. Rule-of-thumb values. Literature data not available for specific building types/categories proposed for the NWC. Values are highly dependent on building design and occupancy/use.*

2. EUIs from US DOE Buildings Energy Data Book (2003)

Table 4-12:
Estimated Building Cooling Demands

Facility	Area/Space	Building Type	Floor Area (ft²)	Floor Area (m²)	NWC Development Phase	Development Year	Peak Cooling Unit Rate (W/ft²)	EUI - Cooling and Ventilation (kWh/ft²)	Peak Demand (MW)	Annual Demand (kWh/yr)
NWC DEVELOPMENT PHASE 1 & 2										
Stock Yard Show and Auction Arenas	Stock Yard Show Arena	Stadium/Arena	20,100	1,867	1	2018	0.7	4.1	1.0	330,000
	Auction Arena	Stadium/Arena	15,000	1,394	1	2018	0.6	7.4	0.3	150,000
Wash Rack building	Wash Rack Building	Warehouse	7,680	714	1	2018	0.7	1.1	0.1	2,000
Water Resource Center	Water Resource Center	Office	150,000	13,936	1	2018	0.7	4.1	1.9	620,000
Livestock	5,000 seat Livestock Arena	Stadium/Arena	130,240	12,100	2	2020	0.6	7.4	1.8	970,000
	Tractor space	Warehouse	1,500	139	2	2020	0.7	1.1	0.0	1,000
	Suites	Commercial	4,000	372	2	2020	0.7	4.1	0.1	1,000
	Livestock Hall	Warehouse	231,500	21,508	2	2020	0.7	1.1	3.1	260,000
	Hall Auction Arena	Stadium/Arena	9,550	887	2	2020	0.6	7.4	0.1	70,000
Equestrian	Horsebarn	Warehouse	220,000	20,439	2	2020	0.7	1.1	2.9	250,000
	Equestrian Events Center	Stadium/Arena	100,500	9,337	2	2020	0.6	7.4	1.4	750,000
	Exhibition space	Exhibition Hall	3,500	325	2	2020	0.6	7.4	0.1	4,000
	Tractor space	Warehouse	1,500	139	2	2020	0.7	1.1	0.0	1,000
	Suites	Commercial	4,000	372	2	2020	0.7	4.1	0.1	3,000
	Equestrian Arena	Stadium/Arena	86,500	8,036	2	2020	0.6	7.4	1.2	650,000
	Covered Indoor Warm Up Area/ Paddocks	Warehouse	48,000	4,459	2	2020	0.7	1.1	0.6	50,000
	Equine Sports Medicine Facility	Commercial	78,664	7,308	2	2020	0.7	4.1	1.0	330,000
NWSS Maintenance and Operations Building	NWSS Maintenance and Operations Building	Office	44,000	4,088	2	2020	0.7	4.1	0.6	180,000
									NWC DEVELOPMENT PHASES 1 & 2 ANNUAL DEMAND SUBTOTAL:	**4,622,000**
NWC DEVELOPMENT PHASES 3 - 6										
1909 Arena	1909 Arena	Stadium/Arena	106,000	9,848	3	2022	0.6	7.4	1.5	790,000
Expo Hall	Exhibition space	Exhibition Hall	430,000	39,949	4	2024	0.6	7.4	6.1	3,210,000
	Ballroom	Commercial	25,000	2,323	4	2024	0.7	4.1	0.3	100,000
	Cafeteria	Commercial	5,000	465	4	2024	0.7	4.1	0.1	4,000
Arena	10,000 seat arena	Stadium/Arena	212,000	19,696	5	2027	0.6	7.4	3.0	1,580,000
	Holding area	Warehouse	25,000	2,323	5	2027	0.4	1.1	0.6	30,000
	Suites, locker rooms, tractor storage, artist rooms, restaurant, ice making, retail, box office, administrative offices	Commercial	58,700	5,454	5	2027	0.7	4.1	0.8	240,000
CSU Facility	3-story building (all program areas)	Office	155,735	14,469	6	2030	0.7	4.1	2.0	640,000
									NWC DEVELOPMENT PHASES 3 - 6 ANNUAL DEMAND SUBTOTAL:	**6,594,000**
									TOTAL NWC DEVELOPMENT ANNUAL DEMAND, ALL PHASES:	**11,216,000**

Notes: 1. *Rule-of-thumb values. Literature data not available for specific building types/categories proposed for the NWC. Values are highly dependent on building design and occupancy/use.*
2. *EUIs from US DOE Buildings Energy Data Book (2003)*

In a district energy system, it is anticipated that not all peak demands will coincide at the same time and the peak demand of the system is expected to be less than the sum of the individual building heating and cooling demands presented in Table 4-11 and Table 4-12. Thus, to estimate the size of the SHR system for the NWC, a diversity factor of 0.80 has been assumed for this study. Table 4-13 presents the estimated SHR system size for the NWC.

Table 4-13:
Estimated SHR Heating and Cooling System Size
(by NWC development phase, including snow melting)

Phase	SHR Heating (MW) Per Phase	Cumulative SHR Heating (MW)	SHR Cooling (MW) Per Phase	Cumulative SHR Cooling (MW)
1	17.0	17.0	2.6	2.6
2	3.8	20.7	10.3	13.0
3	0.7	21.4	1.2	14.2
4	3.0	24.4	5.2	19.4
5	1.8	26.2	3.5	22.9
6	0.6	26.8	1.6	24.5

The use of thermal energy for snow melting may result in a significantly oversized SHR system that would only be periodically used as snowfall accumulation occurs. Table 4-14 illustrates the difference in SHR system sizing when snow melting is excluded.

Table 4-14:
Estimated SHR Heating and Cooling System Size
(by NWC development phase, excluding snow melting)

Phase	SHR Heating (MW) Per Phase	Cumulative SHR Heating (MW)	SHR Cooling (MW) Per Phase	Cumulative SHR Cooling (MW)
1	0.9	0.9	2.6	2.6
2	3.8	4.6	10.3	13.0
3	0.7	5.4	1.2	14.2
4	3.0	8.3	5.2	19.4
5	1.8	10.1	3.5	22.9
6	0.6	10.7	1.6	24.5

Thus, the SHR heating and cooling system size at full buildout without snowmelt represents approximately 25-50% of the thermal capacity in the Delgany Interceptor.

4.19 SCREENING CRITERIA

The screening criteria for evaluating the feasibility of SHR include technical, financial, and environmental considerations. Table 4-15 summarizes the key criteria considered for SHR.

Table 4-15:
SHR Screening Criteria

Title	Criteria	Response
Technical		
General Feasibility	**Are there any limitations on the alternative that would preclude its feasibility? Is there any fatal flaw?**	**Yes or No with narrative**
Technology Options	**What technology options are available and what are the constraints for each?**	**Narrative**
Resource availability	**Is there sufficient thermal energy capacity to provide heating and cooling for the NWC? Is there capacity to serve more than NWC?**	**Yes or No with narrative**
Demand/Supply Cycle	**Does the supply of heat meet the demand cycle from NWC?**	**Yes or No with narrative**
Proof of Technology	**Are there constructed examples and reference projects?**	**Yes or No with narrative**
Benefits	**What are the benefits of the alternative in terms of reducing electricity or natural gas use, Delgany Interceptor sewage temperature, and reducing greenhouse gas emissions?**	**Narrative**
Constructability	**Are there any aspects of the alternative that conflict with the proposed phasing of the Master Plan Program?**	**Yes or No, with narrative**
Financial		
Cost	**What is the ROM life-cycle cost for this technology? What is the ROI? What assumptions are included in these costs?**	**Cost and ROI ($) and assumptions**
Conformance with the NWC Master Plan		
Footprint and Landscape Impacts	**How much space is needed to support the SHR options? What are the constraints around the location of the equipment, and their proximity to the Delgany pipes and the end users?**	**Narrative**
Visitor Experience		

Safety	**How safe is the use of SHR for visitors and pedestrians? Are there any public health and safety concerns?**	**Narrative**
Odor Control	**Is odor control required for any of the technologies? If yes, how successful is the mitigation?**	**Yes and no with narrative**
Partnerships		
Partnership Opportunities	**Does the alternative provide opportunities for partnership with stakeholders such as MWRD, and other potential users of SHR at Delgany outside of the NWC?**	**Yes or No with narrative**

4.20 SEWER HEAT RECOVERY SCENARIOS

The following scenarios have been developed for the NWC to compare alternatives for implementing SHR.

4.20.1 Business-As-Usual

The Business-As-Usual scenario considers the use of natural gas and electricity to meet the full thermal demand at the NWC. This scenario will be used as a basis for comparison with alternatives that make use of SHR as described in Section 5.2.2 and 5.2.3 below.

4.20.2 Meet NWC Heating and Cooling Demands

This alternative considers the use of SHR to meet the heating and cooling demands of the NWC for each development phase, culminating in full buildout in Phase 8 as described in the Master Plan. In this scenario, the SHR system would undergo a series of modular expansions over time within an energy center sized for full buildout. Optimization of the equipment sizing and number of modular expansions will need to be considered during the design development of the SHR system and coordinated with the design of the central heating and cooling district.

4.20.3 Maximize SHR with Delgany

This alternative considers the use of SHR and thermal storage to maximize the thermal energy extracted from the Delgany Interceptor. In this alternative the thermal supply would exceed the thermal demands of the NWC and there would be additional capacity to provide heating and cooling to potential partners adjacent to the NWC.

4.21 RECOMMENDATIONS AND NEXT STEPS

Based on the analysis of thermal energy available in the Delgany interceptor, there is an opportunity to make use of the Delgany interceptor for heating and cooling at the NWC. There appears to be sufficient thermal energy supply to operate a SHR system with heat pumps to meet the heating demands for the buildings contemplated at the NWC. Similarly, there is capacity in the Delgany interceptor to provide cooling in a district system for the NWC, with waste heat being rejected back in to the Delgany interceptor in the summer time.

To meet the thermal energy demands at the NWC, the campus would require the use of a district energy system using heat pumps and a distribution loop to provide heating and cooling for individual buildings within the NWC. Examples of SHR systems indicate that SHR systems can be cost-effective and has the potential to reduce the electricity and natural gas used to provide domestic hot water heating and space heating in the buildings, while at the same time reducing the sewage temperature in the Delgany interceptor.

If the NWC is contemplating the use of innovative technologies, it is recommended that further analysis and design development be undertaken to evaluate and refine the sizing of the SHR system in combination with thermal storage. The annual and peak heating and cooling demands for individual buildings should also be refined and confirmed at the design stage.

Screening criteria have been developed to assist in the evaluation of the potential for SHR and it is recommended that the screening analysis be conducted for each of the identified scenarios to confirm the scope and feasibility of SHR at the NWC.

5.1 THE NWC WITHIN THE REGION

The Denver metropolitan area has great open space amenities. Rocky Flats National Wildlife Refuge, a 5,000 acre preserve, and Standley Lake are anchoring open spaces for the metro area's northwest quadrant.

Similarly, the 16,000 acre Rocky Mountain Arsenal Wildlife Refuge, one of the largest urban wildlife sanctuaries in the country, is a major open space in the metro area's northeast quadrant. Ultimately, the Rocky Mountain Greenway will connect these signature open spaces with Rocky Mountain National Park. As illustrated, the NWC is located near the confluence of the region's major trail systems, and the Riverfront Open Space within NWC can be seen as a gateway to the metro area's major open spaces.

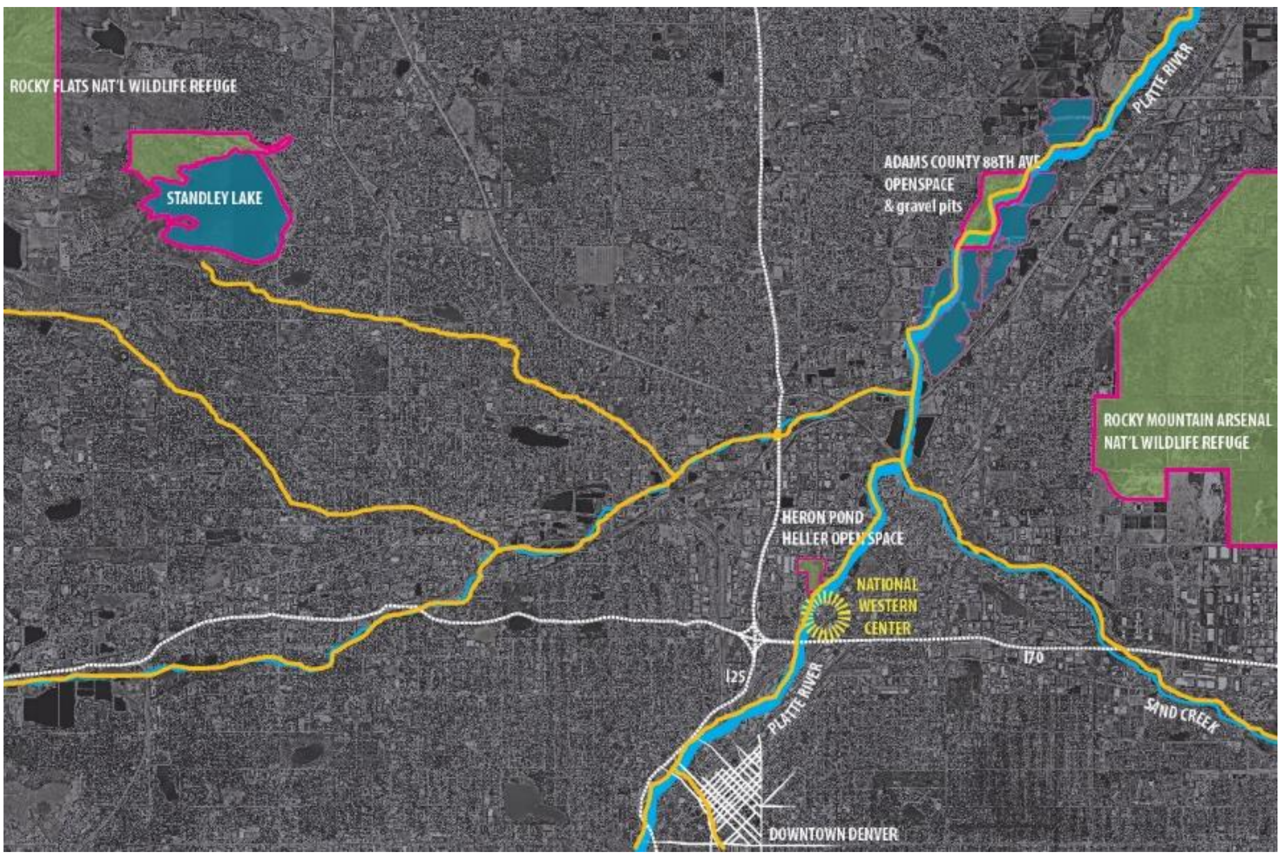


Figure 5-1:
Region Map – NWC and Regional Open Spaces

5.2 NWC WITHIN THE CITY

The NWC and the Riverfront Open Space are at the epicenter of an evolving neighborhood that will be one of the region's most unique places. The river connects the NWC with downtown and the region via trails. The historic neighborhoods of Elyria-Swansea and Globeville are rich with culture, and will benefit from the new connections across the river as detailed in the NWC Master Plan. The planned restoration of the Heller Open Space and Heron Pond will add an additional signature natural open space adjacent to the NWC. Add to that the deep history and culture of the National Western Stock Show and a picture of a part of the city which incorporates nature, water, history and culture emerges - a truly unique place within the region.

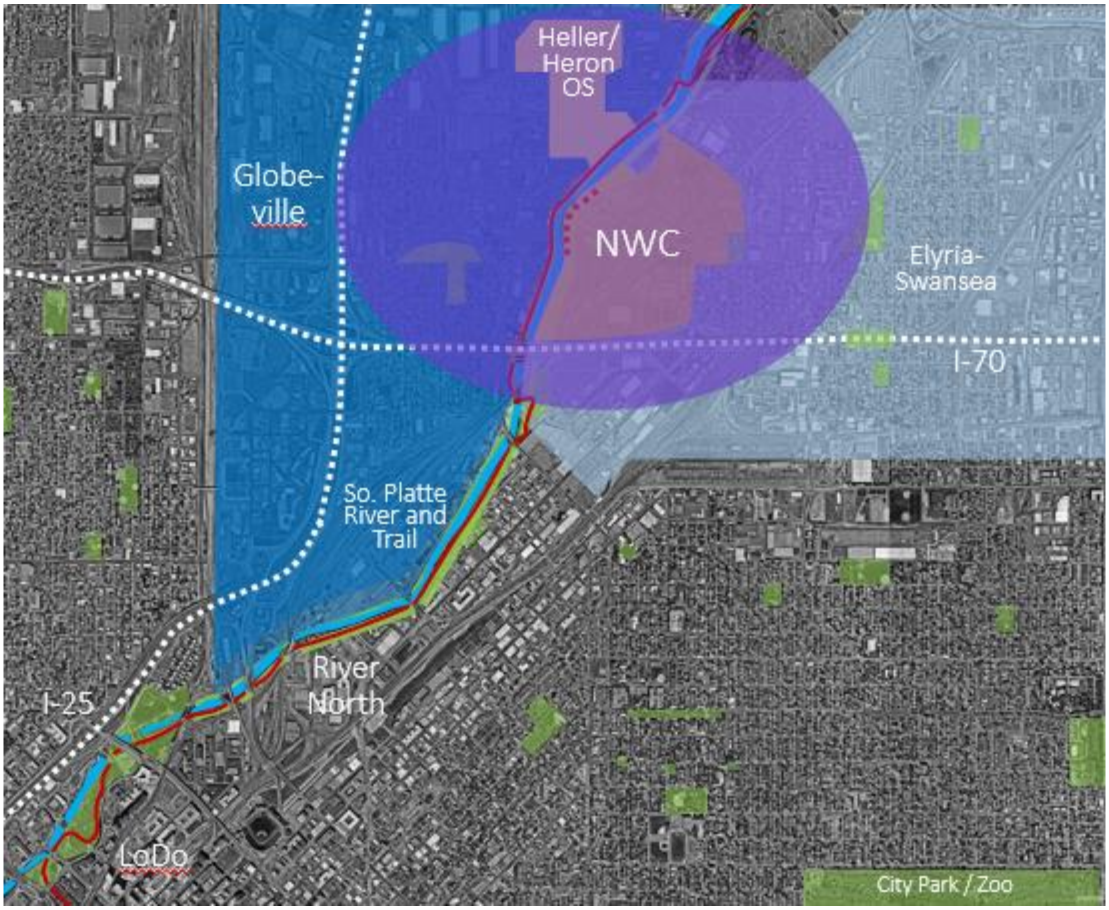


Figure 5-2:
Area Map – NWC and Surrounding Neighborhoods

5.3 CONNECTING NEARBY NEIGHBORHOODS TO THE RIVER

Connections from east to west through the NWC site are non-existent today. The NWC Master Plan calls for vehicular/bike/ped river bridges at Bettie Cram Drive/49th Avenue and 51st Avenue, thereby connecting the previously separated neighborhoods. Both connections run through Riverfront Open Space, making the open space and the river an available and connected community amenity. Additionally, the neighborhoods will benefit from the connections to the regional trail system, allowing access to the entirety of the Front Range’s extensive trail system. So, connecting Elyria-Swansea and Globeville to and along the river and to one another will create a more cohesive community, unlock recreation and educational opportunities at the water’s edge, and enable families to enjoy the natural landscape along the South Platte.

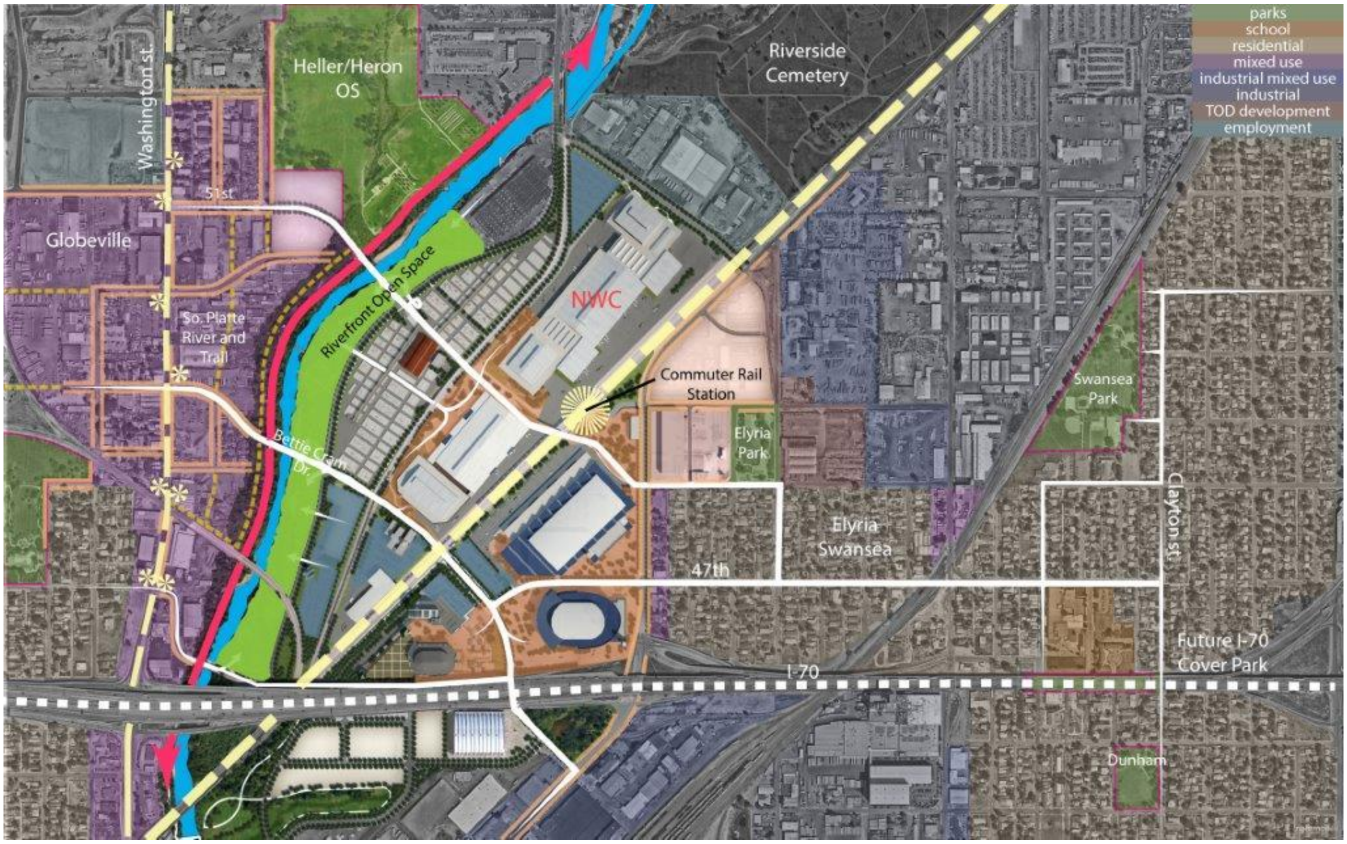


Figure 5-3:
Area Map – NWC and Connected Neighborhoods

5.4 NWC MASTER PLAN

Completed in 2015, the NWC Master Plan is founded on nine Guiding Principles as illustrated in the adjacent diagram. While all are significant, "Engage River and Nature," "Community and Neighborhood Integration," and "Embrace an Ethic of Regeneration" are critical influences on the Riverfront study that must be considered and integrated. Aspirations for integration and regeneration should not be limited to the NWC site, but must strive to create connections to and from Globeville on the west and Elyria-Swansea on the east. The Globeville and Elyria-Swansea Neighborhood Plans recommend improvements to land uses and connections to and across the South Platte River that will allow citizens to more easily access the river. As such, the synergy of activity within the NWC, the trail connections along the South Platte, and the potential for habitat restoration along the river make the Riverfront Open Space of prime importance not only of the NWC but to the neighborhoods, city and region.

Today, the Delgany Interceptor (DI) is a major impediment to pedestrians desiring to access the river from the NWC (see section 5.8.2. below). To mitigation this condition, the NWC Master Plan recommends the DI be buried or relocated, however relocation of the pipes was not considered in the baseline budget developed during the Master Plan process.

5.5 PURPOSE OF THIS STUDY

The purpose of this study is to understand the impact of either the Delgany Interceptor (DI) remaining in place (the *in situ* alternatives) or relocating the pipes elsewhere within the NWC campus to facilitate the Partners' ability to create open space along the South Platte River within the NWC campus that meets the goals and intentions of the NWC Master Plan. Specifically, we are to studying alternative concepts for maximizing the perceived and actual connectivity from the NWC to the river, and the programmatic opportunities afforded in each alternative.

It is important to note that this study is <u>neither</u> a design nor a programming exercise. The forthcoming Campus Placemaking Study will refine and finalize the programmatic desires of the Partners, examine the comprehensive Public Realm goals for the campus, and develop design standards and guidelines for the campus. Design for the Riverfront Open Space will follow that study.

This study will serve to inform the Campus Placemaking Study by illustrating the potential of the Riverfront Open Space as impacted by the location of the Delgany Interceptor pipes. This analysis attempts to answer the following questions:

- How does the location of the pipes impact the Partners' ability to meet the goals of the Master Plan for the riverfront?
- Is one pipe alignment preferable over another, when considering the development potential of the riverfront?
- What can be accomplished along the riverfront if the pipes are left in place, and how would the goals of the Master Plan be achieved in that scenario?

In light of this goal, all renderings of the Riverfront Open Space Alternatives are intended to be illustrative of the <u>potential</u> for Open Space development, and are not prescriptive. Quantities of program areas are conceptual and intended to inform the Riverfront Technical team about the programmatic potential of each Alternative so they may properly evaluate it. These are not conceptual design drawings for the Riverfront Open Space.

5.6 STUDY AREA

Where the riverfront open space within NWC extends from 47th on the south to the existing International Paper Company building on the north, the focus area of this study is bounded by the proposed 49th Avenue/Bettie Cram and 51st Avenue bridges. The DI runs above-grade throughout this portion of NWC's river frontage. Riverfront areas between 49th and I-70 are not included in this study.

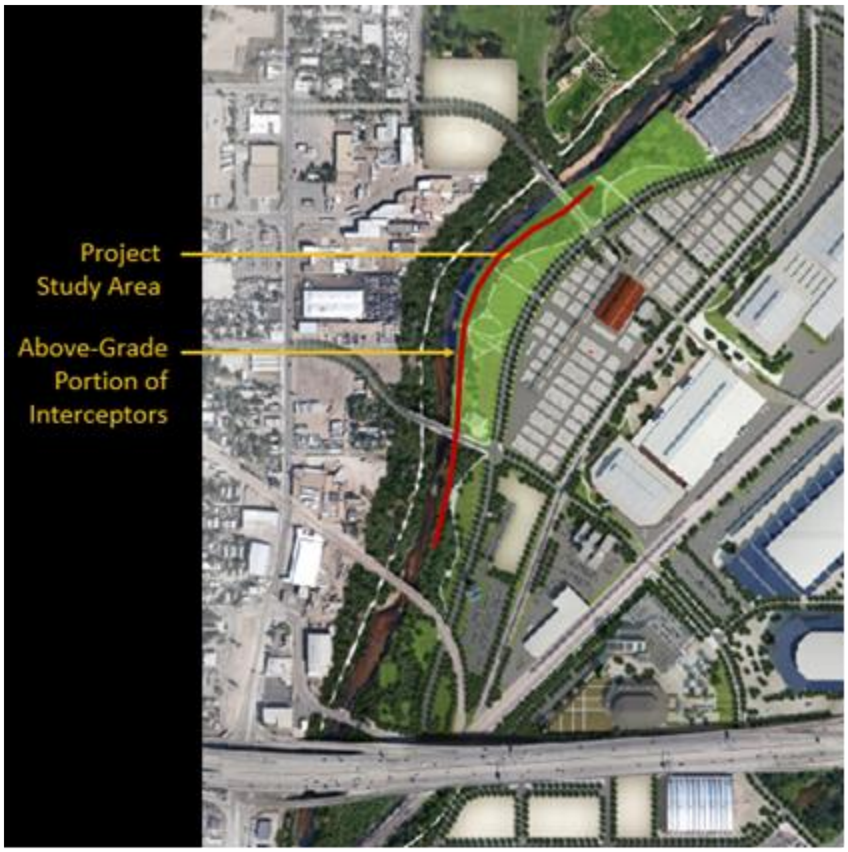


Figure 5-4:
NWC Plan and Project Study Area

5.7 RIVERFRONT OPPORTUNITIES

The location of the Riverfront Open Space (ROS) along the South Platte is a critical element in the success of the NWC. Situated between the river and the NWC, the open space is the most important link between the active portion of the NWC and the river's natural environment and, with strengthened connections from the adjacent neighborhoods, provide ready access to the river and regional trail system to Globeville and Elyria-Swansea.

This riverfront zone varies in character, due mainly to the relationship between the river's edge and the adjacent slope up to the DI. Depending on its severity, this slope either limits or promotes pedestrian access to the water, the potential for wetlands restoration along the river, and the type of habitat restoration that is possible.

5.7.1 River Bend Reach

The reach of river between the proposed Betty Cram/49th Avenue and 51st Avenue bridges, which encompasses the majority of the above-ground DI pipes, is centrally located from north to south within the NWC site. Pedestrian connections from the NWC to the river are most suited to be made within this reach. A number of inherent opportunities are found within this reach that set this portion of the NWC riverfront apart from others further south.

1. Land Use Adjacencies: The location of the open space in this area is directly adjacent to the Stockyards across the future National Western Drive, leading to a strong synergy between the Stockyards and the open space. The Stockyards will be an active place throughout the year. Providing the ability of the Riverfront Open Space to handle spill-over or discreet activities related to Stockyard events will be important in functionally linking the NWC to the river and enhancing activities along the river. Additionally, connections across the river at Bettie Cram (49th Avenue) and 51st Avenue (shown in yellow) will allow pedestrians and bikers to access this portion of the open space from Globeville and the regional trail on the river's west bank.

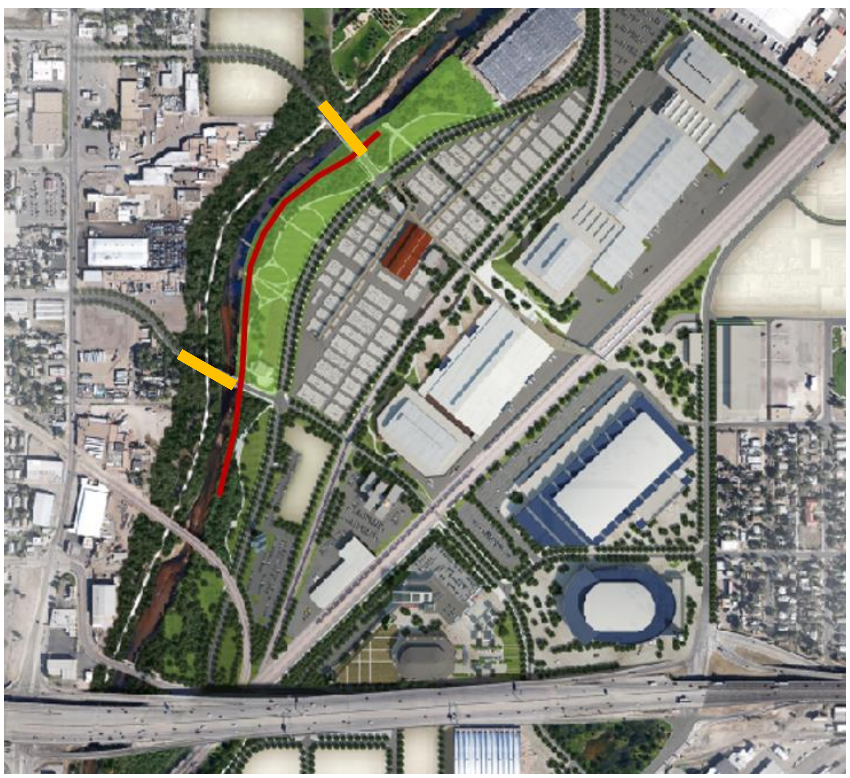


Figure 5-5:
NWC Riverfront Open Space Connections

2. Existing slopes from the existing DI alignment down to the river are comparatively gentle in this reach, with sandbars present along the river that more graciously allow pedestrian access to the water's edge. To the north and south of this section, the slopes to the river are steeper, making pedestrian access to the river's edge more difficult.

Figure 5-6:
East Bank of South Platte River (looking South) at NWC

3. New connections from the neighborhoods to the river through the NWC will complete important links that will unlock recreational, historic, cultural and educational opportunities for adjacent neighborhoods which do not exist today.

Figure 5-7:
NWC Neighborhood Connections

5.7.2 Habitat

Habitat restoration along the South Platte is a key goal not only of the NWC Master Plan, but has also been the focus of other studies including the Urban Waterways Restoration Study currently under way by the US Army Corps of Engineers. Wetland and habitat restoration has occurred elsewhere along the river, including Commons Park, City of Cuernavaca Park, Frog Hollow Park, Johnson Habitat Park, Pasquinel's Landing and Grant Frontier Park. The opportunities for restoration within the NWC Campus are to some degree related to the location of the DI. By moving the DI pipes east away from the river, the banks along the river can be graded back to allow for terraced landforms, each supporting a unique micro-ecology related to water levels of the South Platte. Restoration on the NWC side of the river should be considered in context of recommendations of the USACE study, and restoration activities proposed as part of the Heron Pond/Heller Open Space master planning efforts. If executed correctly, these three efforts could result in a large aggregated zone of habitat restoration that would be an educational, recreational and ecological model for urban open space in the arid West.

5.8 RIVERFRONT CONSTRAINTS

5.8.1 Site Grades

Once meandering through North Denver, the South Platte River was channelized to make room for development during the later 19th and early 20th centuries. Sloping areas near river were filled to gain buildable land for stockyards, meat packing houses and other related industries. Flat, developable ground extended almost to the river's edge, creating steep slopes from the NWC site down to the riverbank. Today, these slopes act as a barrier for people to access the river's edge, creating a sense of isolation when down by the water. As demonstrated later in this report, the location of the DI does not allow laying back these steep slopes.

5.8.2 Delgany Interceptor

The Delgany Common Sewer (DCS) was constructed in phases between 1892 and 1937. To accommodate increased flows, construction of the Delgany Interceptor, a second pipe running parallel to the DCS, began in 1979. These two pipes, which run below grade along a majority of their alignment, are located above grade for a length of approximately 1,900 feet through the NWC site. At a maximum of 14’ above grade, they are a barrier to pedestrian access to the river, and create a visual wall for visitors along the riverbank.

The associated Lift Station #5 allows the operation of the existing siphon that transfers flows from the DI, beneath the river, to the interceptor within the river’s west bank. The Lift Station #5 structure can be modernized and downsized, but functionally will need to remain. Both the lift station and siphon will require ongoing maintenance vehicle access.

Additional information pertaining to the existing Lift Station #5 can be found in Section 3 of this Report.

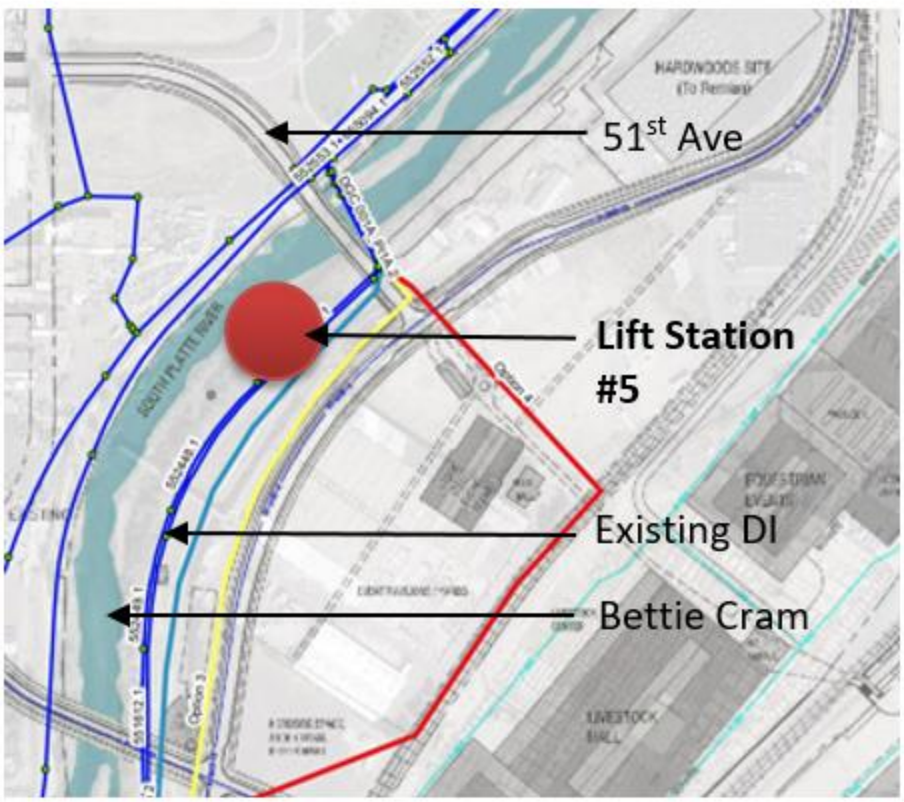


Figure 5-8:
Delgany Interceptor and Lift Station #5

5.8.3 Flood Levels

The South Platte River (SPR) acts as a major stormwater conveyance for the Denver metropolitan area. The US Army Corps of Engineers (USACE) manages dam releases from three upstream flood control reservoirs (Chatfield, Cherry Creek and Bear Creek), however, the river’s 100-year flood flows are dominated by uncontrolled storm runoff. Modifications to the river that result in a rise in the 100-year

flood elevation are not allowed due to floodplain sensitivity in this reach of the river and the presence of an existing flood protection levee system on the west bank of the river. Upstream of the NWC campus the 100-yr floodplain is not contained within the main river channel. Any increase in 100-year flood levels would worsen this condition by sending additional flood-water into the west overbank, impacting numerous homes and businesses. Increases in 100-year flood elevations at buildings are prohibited by Federal, State, and local floodplain regulations. Any increases in flood elevations in this reach would also decrease the level of flood protection that the levee currently provides and could jeopardize the accreditation of the levee by FEMA. As such, any modification that contributes to 100-year flood level rise is not allowed.

Relative to the DI within the NWC campus, the existing 100 year flood level is approximately at the base of the pipes' supporting structure, as illustrated by the red line in the photo above.

As part of this study, the proposed topographic grading for four separate ROS alternatives were computer modeled to calculate the impacts of the various alternatives on the 100-year floodplain to determine whether any of the conceptual conditions create a rise in 100-year flood elevations. The computer modeling included the use of an existing conditions model developed by the Urban Waterways team as a baseline, and mapping the proposed ROS improvements against that baseline.

5.9 EVALUATION CRITERIA

The evaluation process for determining the best course of action relative to both the DI and associated open space requires clear criteria with which each alternative can be weighed. While this study will not identify a preferred alternative, it will provide information and criteria to assist the NWC project team in determining the best alternative. The following table lists each criterion, with an emphasis on *Gating/Yes-No,* and *Qualitative*. Refer to each Riverfront Alternative for additional information.

Table 5-1:
Evaluation Criteria for Riverfront Open Space Alternatives

Criteria Title	Criteria Description
Yes/No	
Floodplain Impacts	The riverfront improvements must result in "no rise" to the 100-yr floodplain. Does the alternative meet this requirement (either outright or via mitigation within the NWC project area)?
MWRD Maintenance Access	Does the alternative provide MWRD with necessary/required access to maintain the pipes?
Sewer Heat Recovery	Does the alternative enable the installation of a SHR system, should it be deemed feasible?
General Feasibility	Does the alternative pass the "fatal flaw" test in terms ofother technical feasibility?
Odor Impacts	does not impede odor mitigation?
Qualitative	**How well does the alternative enable the NWC to design a space/amenity that...**
Master Plan Conformance	creates flat open space that could be used for festivals, events or informal activities, compared to other alternatives?
	provides flexibility to accommodate MP WQ volumes while maintaining quality of amenity and of program?
	is compatible with easement and entitlement restrictions on programmatic flexiblity with Riverfront Open Space?
	provides visitors with varied forms of visual and physical access to the river and to nature?
	enables connectivity from campus OS within the NWC site to the Riverfront open space?
	Create places for education and outreach on site related to the Platte River and its watershed through design?
Sustainability	Help the City reach its 2020 Sustainability goals related to Water Quality?
	Contribute to a healthy and diverse river habitat and provides biological corridor linkage to other habitats?
Safety & Accessibility	Contributes to the ability of the NWC to design reate a safe environment for visitors and pedestrians?
	Facilitate safe and comfortable access to the river edge and program areas for all visitors?
Habitat Restoration	is compatible with design solutions that include riparian habitat restoration?
	Creates adverse impacts relative to the goals USACE Urban Waterways Study?

5.10 DELGANY INTERCEPTOR ALIGNMENTS VS. RIVERFRONT ALTERNATIVES

The various DI alignments will directly impact the planning and design of the Riverfront Open Space (ROS). The table below details how the DI alignments (A through E) relate to the ROS alternatives (1 through 5):

- DI Alignments refer to the location of the DI within the NWC campus, including the option to leave the pipes in their present location (Alignment A). Diagrams within Section 3 of this report illustrate each of the DI alignments.

- Riverfront Alternatives refer to the different potential open space configurations that are made possible by each DI Alignment.

Table 5-2:
Relationship Between Interceptor Alignment and Riverfront Alternative

Interceptor Alignment	Riverfront Alternative
A. *In Situ* – remains in its current location	1. Pipe remains exposed, and is bridged over
	2. Partially buried on the east side
	3. Fully buried; "bermed" over
B. Pipes moved to the east, but still within the open space	4. Fully buried within the eastern portion of the open space
C. Under National Western Drive	5. Pipes out of the open space
D. Under the Stock Yards	
E. Under or adjacent to the consolidated rail corridor	

Each of the DI Alignments was reviewed from a constructability perspective and to identify any possible limits the Alignment might impose on NWC development in the future. This review is described in Section 3 of the Study. The review concluded that Alignment D and Alignment E present significant conflicts with proposed NWC infrastructure and site uses, and were eliminated from further consideration. Alignments A, B and C were retained for additional evaluation and consideration.

5.11 RIVERFRONT ALTERNATIVES

Inherent in each DI alignment are opportunities and constraints that impact the potential physical form and function of the ROS. Within this section, five different Riverfront Open Space Alternatives illustrate potential open space configurations based on each interceptor alignment. While not recommending specific design solutions, each ROS Alternative evaluates the impact of interceptor alignments on the NWC's ability to create usable public space, encourage quality user experiences, accommodate the NWC Master Plan's recommendation for water quality treatment within the ROS, and allow restoration of natural habitat along the river.

5.11.1 Riverfront Alternative 1: In-Situ, Bridge Over the Pipes

This Alternative assumes Interceptor Alignment A is selected, where the DI pipes remain in place. No earthwork or berming on either the river side or east of the pipes is anticipated.

A description of the impacts of this alternative is as follows:

- Floodplain Impacts:
    - Encroachment into the 100-year floodplain causing increase of the 100-year flood elevation does not occur.
- User Experience:
    - While not eliminating the visual barrier the DI currently presents, pedestrian elements including ramp and stair structures can convey pedestrians over the DI, allowing circulation between the east and west sides of the pipes.
    - Bringing pedestrians to the top of the DI gives patrons a high prospect which would provide a unique view of the river below and views back to the NWC. An opportunity for a boardwalk exists along the top of the pipes, allowing patrons to move parallel to the river and ROS in a way that is highly visible.
    - A “Skywalk”- an elevated walkway at the same elevation as the top of the DI would allow users to walk out and over the native landscape below and through the tree canopy, would be a unique experience along the South Platte in Denver.
    - Not including the boardwalk and/or Skywalk would diminish the use experience associated with this alternative, limiting pedestrians to ramps and stairs to go over, then back down the other side of the DI. The high prospect previously discussed would happen only at select places along the DI.
    - The DI would present a strong visual buffer for visitors at the river’s edge looking up-slope, potentially giving a sense of isolation from the NWC.
- Water Quality:
    - This alternative would not hinder the NWC’s ability to provide water quality facilities per the NWC Master Plan.
- Safety:
    - With the DI in place, pedestrians moving over and down the riverbank to the water’s edge may experience a sense of isolation, increasing a perceived lack of safety.
    - The boardwalk and Skywalk would help to address this perception by keeping visitors high and in visual contact with the NWC and ROS to the east.
- Habitat Restoration:
    - As grades between the DI and river would remain primarily unchanged, habitat restoration would be much more limited and more difficult to achieve than in other alternatives. Typical habitat restoration practices include additional vegetation and wet-land benches, both of which decrease the flood capacity of the channel in this case. Due to the no-rise criteria any reduction in flood conveyance must be mitigated, which is difficult due to steep existing grades and the inability to lay those slopes back.
- Cost:
    - No cost associated with relocation of the DI pipes.
    - As no earthwork fill is added either side of the DI, earthwork costs would be minimal.

- Constructing a boardwalk and/or Skywalk would add significant expense to the project.

The exhibits on the following pages illustrate the site impacts inherent in Riverfront Alternative 1.

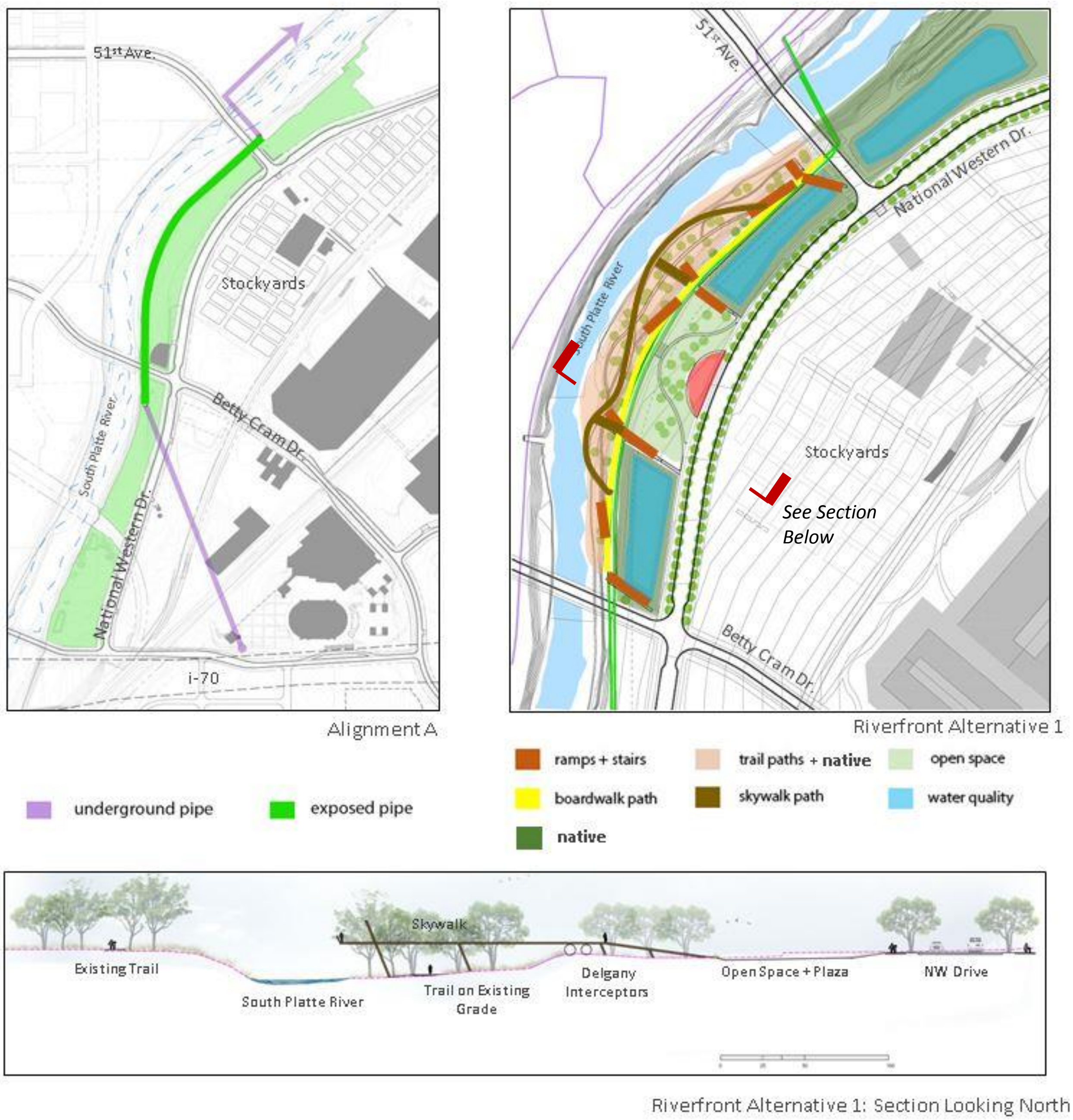
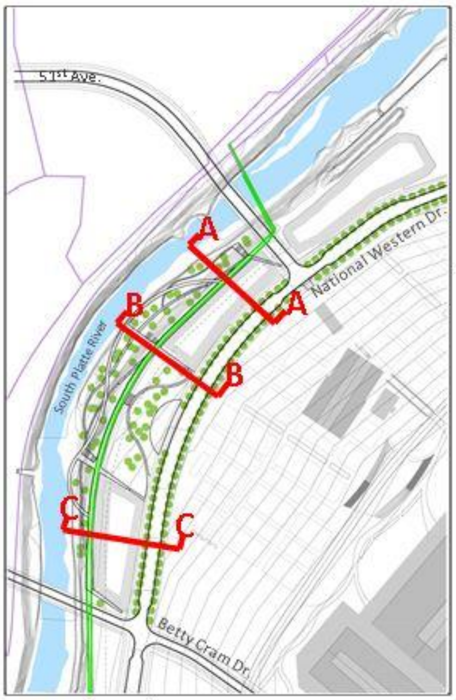


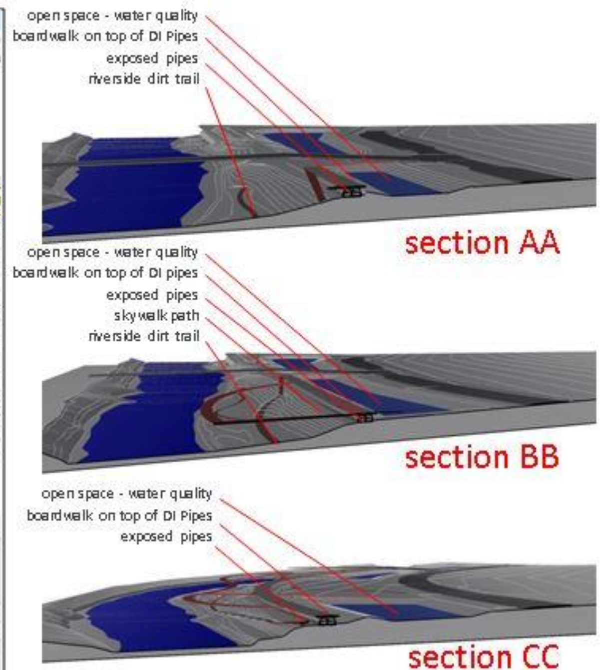
Figure 5-9:
Alternative 1 – Plans and Section

As seen in the section above, existing grades (pink dashed line) and the DI remain in place, resulting in the need for a series of ramps and stairs to promote pedestrian access over the DI. Boardwalks and Skywalks, while requiring significant expenditures, help to overcome the constraint of leaving the pipes in place by allowing visitors to walk along the top of the pipes (boardwalk) and out over the native landscape below (Skywalk), creating a river and landscape experience that is visually connected with the ROC and NWC to the east.

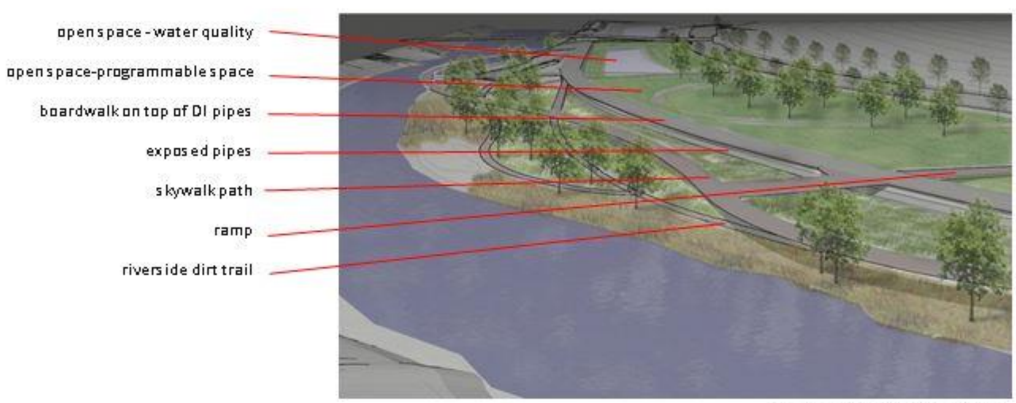
The following exhibits illustrate various potential aspects of Alternative 1, including grades, water quality, circulation, riverfront access and open space treatments.



Riverfront Alternative 1: Section Cut Locations



Riverfront Alternative 1: Section Perspectives



Perspective Looking North

Riverfront Alternative 1 Inspirational Imagery: Stairs and Ramps at DI; Promenade Along DI

Figure 5-10:
Alternative 1 – Plans, Sections and Perspectives

Table 5-3:
Alternative 1 Evaluation

Alternative is highly flexible to accommodate programmatic/ qualitative desire | Alternative is modestly flexible to accommodate programmatic/ qualitative desire | Alternative has limited flexibility to accommodate programmatic/ qualitative desire

This matrix illustrates the evaluation of Riverfront Alternative 1. Green checkmarks indicate conformance (yes/no) with stated criteria. Colors indicate level of conformance with qualitiative criteria as described above.

Criteria Title	Criteria Description	1 In Situ - Exposed
Yes/No		
Floodplain Impacts	The riverfront improvements must result in "no rise" to the 100-yr floodplain. Does the alternative meet this requirement (either outright or via mitigation within the NWC project area)?	✓
MWRD Maintenance Access	Does the alternative provide MWRD with necessary/required access to maintain the pipes?	✓
Sewer Heat Recovery	Does the alternative enable the installation of a SHR system, should it be deemed feasible?	✓
General Feasibility	Does the alternative pass the "fatal flaw" test in terms ofother technical feasibility?	✓
Odor Impacts	does not impede odor mitigation?	✓
Qualitative	**How well does the alternative enable the NWC to design a space/amenity that...**	
Master Plan Conformance	creates flat open space that could be used for festivals, events or informal activities, compared to other alternatives?	
	provides flexibility to accommodate MP WQ volumes while maintaining quality of amenity and of program?	
	is compatible with easement and entitlement restrictions on programmatic flexiblity with Riverfront Open Space?	
	provides visitors with varied forms of visual and physical access to the river and to nature?	
	enables connectivity from campus OS within the NWC site to the Riverfront open space?	
	Create places for education and outreach on site related to the Platte River and its watershed through design?	
Sustainability	Help the City reach its 2020 Sustainability goals related to Water Quality?	
	Contribute to a healthy and diverse river habitat and provides biological corridor linkage to other habitats?	
Safety & Accessibility	Contributes to the ability of the NWC to design reate a safe environment for visitors and pedestrians?	
	Facilitate safe and comfortable access to the river edge and program areas for all visitors?	
Habitat Restoration	is compatible with design solutions that include riparian habitat restoration?	
	Creates adverse impacts relative to the goals USACE Urban Waterways Study?	

The following table compares approximate acreages of the various landscape types within each ROS Alternative, with Alternative 1 highlighted.

Table 5-4:
Landscape Type Areas per Alternative

LANDSCAPE TYPE- RIVERFRONT ALTERNATIVE 1	ACRES*	FLEXIBILITY OF USE
Native Grassland Restoration, Including Water Quality (WQ) Areas WQ Data: WQ acreage = 1.75 Ac WQ volume/capacity = 18.8 Acre Feet (AF). Meets NWC MP requirements	Up to 5.1	This includes sloping areas not suitable for wetlands/habitat restoration or Festival areas, but are inclusive of WQ areas. This area could be reduced to allow an increase in the quantity of Festival areas, but may limit the amount of WQ capacity accommodated within the ROS and recommended within the NWC Master Plan.
Wetland / Habitat Restoration- Areas Near River Water Level	Up to 0.9	Areas near the river and close to the average water level comprise this category, where wetlands can reasonably be expected to thrive. As the DI will remain in place in Alternative 1, grades between the DI and river banks cannot be significanlty changed without impacting the 100-year flood levels. With this in mind, the area in which wetlands/habitat restoration is limited.
Festival Turf Areas- Flat Areas Suitable for Gatherings	Up to 2.3	This designation includes level turfgrass areas that can be used for informal and formal events, which would work well as overflow spaces for events held within the Stockyards. Should structures be planned within the ROS, these flat areas would provide good siting for construction. As the area east of the DI is fixed between the pipes and NW Drive, the amount of space is related to the amount of WQ ponds planned for the area.

**Acreage shown is based on the Alternative 1 plan diagram, and are not prescriptive of a final design. Refer to "FLEXIBILITY OF USE" notes for additional information pertaining to tradeoffs if various landscape types are expanded.*

5.11.2 Riverfront Alternative 2: In-Situ, Berming Up To Pipes on East Side

This Alternative assumes the DI pipes remain in place (Alignment A), with earthwork/fill bringing the grade east of the pipes even with the tops of the pipes, allowing free movement from the ROS to the pedestrian boardwalk along the top of the pipe. To reach the river, stairs and ramps will be needed on the west side of the DI. Structures are needed to access the top of the pipe and back down the other side to the river's edge. As with the Riverfront Alternative 1, the high prospect from the top of the interceptors provides a unique view of the river below, and creates the opportunity for a promenade atop the pipes. As the existing DI may be unable to structurally support the fill placed between the DI and National Western Drive, a retaining wall will be needed along the DI's east face.

A description of the impacts of this alternative is as follows:

- Floodplain Impacts:

  - Encroachment into the 100-year floodplain causing increase of the 100-year flood elevation does <u>not</u> occur.
- User Experience:
  - By raising the grade on the east side of the DI, pedestrians can walk across National Western Drive, across the ROS and onto a promenade/walk structure atop the pipes. This would create an overlook to the river.
  - Ramps and stairs would still be needed to allow visitors to access the river-side of the DI from the boardwalk on top of the pipes.
  - As with Alternative 1, bringing pedestrians to the top of the DI gives visitors a high prospect which would provide a unique view of the river below and views back to the NWC. An opportunity for a boardwalk exists along the top of the pipes, allowing patrons to move parallel to the river and ROS in a way that is highly visible.
  - A "Skywalk"- an elevated walkway at the same elevation as the top of the DI would allow users to walk out and over the native landscape below and through the tree canopy, would be a unique experience along the South Platte in Denver.
  - While not to the same degree, not including the boardwalk and/or Skywalk would diminish the user experience associated with this alternative, limiting pedestrians to ramps and stairs to access the river-side of the DI.
  - The DI would still present a strong visual buffer for visitors at the river's edge looking up-slope, potentially giving a sense of isolation from the NWC.
- Water Quality:
  - This alternative would not hinder the NWC's ability to provide water quality facilities per the NWC Master Plan.
- Safety:
  - With the DI remaining in place, the visual barrier of the pipes at the top of the slope separates the experience at the river's edge from the ROS. Pedestrians moving down the riverbank to the river bank may experience a sense of isolation from the activity and visual connection of the main portion of the ROS, increasing a perceived lack of safety.
  - The boardwalk and Skywalk would help to address this perception by keeping visitors at a high prospect and in visual contact with the NWC and ROS to the east.
- Habitat Restoration:
  - As grades between the DI and river would remain primarily unchanged, habitat restoration would be much more limited and more difficult to achieve than in other alternatives. Typical habitat restoration practices include additional vegetation and wet-land benches, both of which decrease the flood capacity of the channel in this case. Due to the no-rise criteria any reduction in flood conveyance must be mitigated, which is difficult due to steep existing grades and the inability to lay those slopes back.
- Cost:
  - No cost associated with relocation of the DI pipes.
  - Significant fill would be required to raise the grade east of the DI.
  - A retaining wall would be required for the length of the pipe where grades would be raised, as placing fill against the existing pipe structure would not be structurally viable.
  - Constructing a boardwalk and/or Skywalk would add significant expense to the project.

The following exhibits illustrate the site impacts inherent in Riverfront Alternative 2.

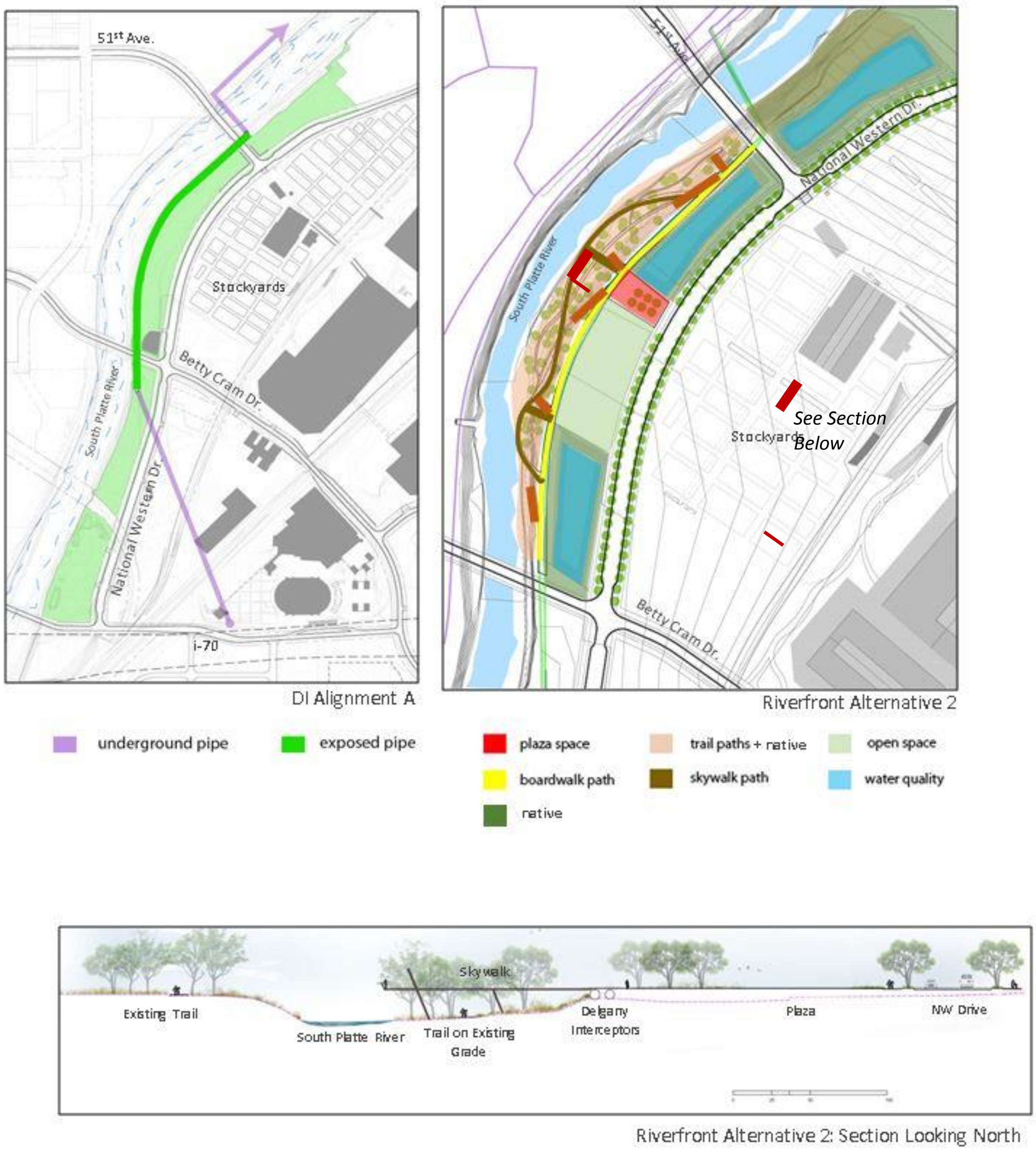
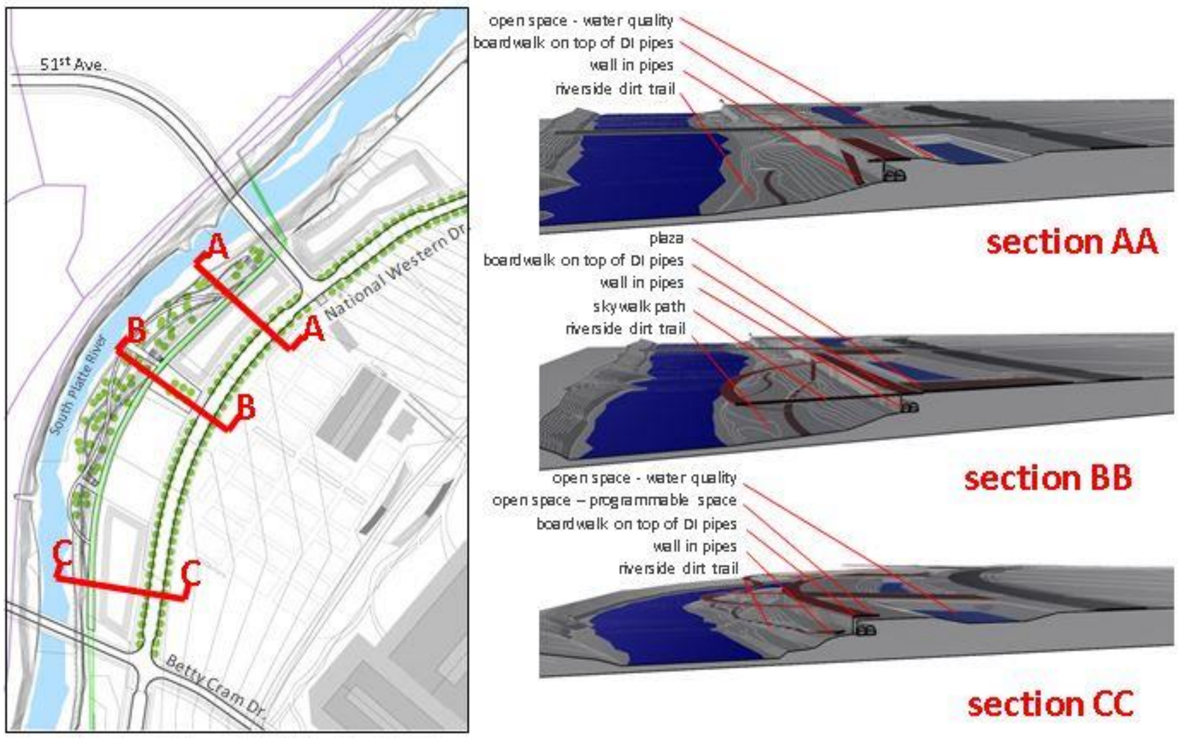


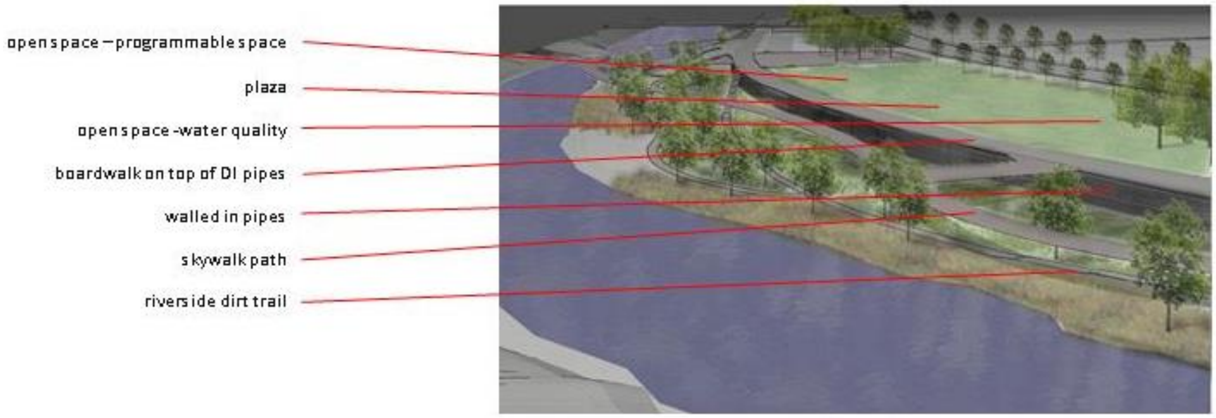
Figure 5-11:
Alternative 2 – Plans and Section

As illustrated in the section above, Alternative 2 involves earthwork fill bringing the surface of the ROS to the level of the top of the DI. This allows seamless access from the ROS to a vantage point on top of the pipes, at which point pedestrians can descend stairs and ramps to the west side of the DI and to the river's edge or along the boardwalk atop the pipes (if constructed). The Skywalk, if built, would give visitors a unique vantage point of the river and native landscape areas below.



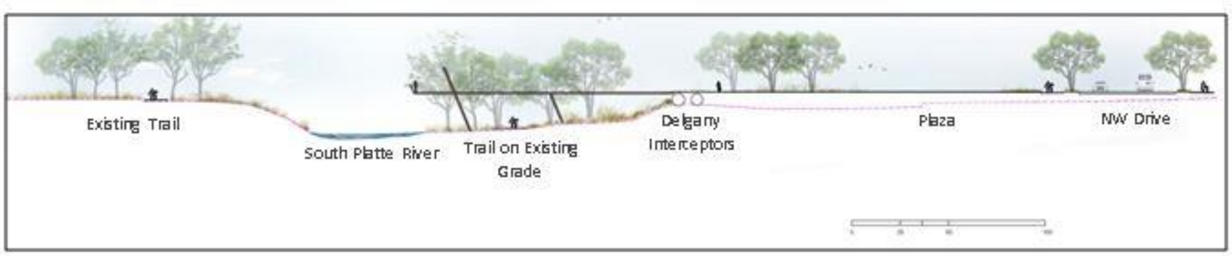
Riverfront Alternative 2: Section Key Plan

Figure 5-12:
Alternative 2 - Plan and Section



Riverfront Alternative 2: Section Perspective

Riverfront Alternative 2 Inspirational Imagery: Raised Walks, Promenade Above DI, Skywalk



Riverfront Alternative 2: Section Looking North

Figure 5-13:
Alternative 2 – Perspective, Concepts and Section

Table 5-5:
Alternative 2 Evaluation

Alternative is highly flexible to accommodate programmatic/ qualitative desire	Alternative is modestly flexible to accommodate programmatic/ qualitative desire	Alternative has limited flexibility to accommodate programmatic/ qualitative desire

This matrix illustrrates the evaluation of Riverfront Alternative 2. Green checkmarks indicate conformance (yes/no) with stated criteria. Colors indicate level of conformance with qualitiative criteria as described above.

Criteria Title	Criteria Description	In Situ - Partially Buried 2
Yes/No		
Floodplain Impacts	The riverfront improvements must result in "no rise" to the 100-yr floodplain. Does the alternative meet this requirement (either outright or via mitigation within the NWC project area)?	✓
MWRD Maintenance Access	Does the alternative provide MWRD with necessary/required access to maintain the pipes?	✓
Sewer Heat Recovery	Does the alternative enable the installation of a SHR system, should it be deemed feasible?	✓
General Feasibility	Does the alternative pass the "fatal flaw" test in terms ofother technical feasibility?	✓
Odor Impacts	does not impede odor mitigation?	✓
Qualitative	**How well does the alternative enable the NWC to design a space/amenity that...**	
Master Plan Conformance	creates flat open space that could be used for festivals, events or informal activities, compared to other alternatives?	
	provides flexibility to accommodate MP WQ volumes while maintaining quality of amenity and of program?	
	is compatible with easement and entitlement restrictions on programmatic flexiblity with Riverfront Open Space?	
	provides visitors with varied forms of visual and physical access to the river and to nature?	
	enables connectivity from campus OS within the NWC site to the Riverfront open space?	
	Create places for education and outreach on site related to the Platte River and its watershed through design?	
Sustainability	Help the City reach its 2020 Sustainability goals related to Water Quality?	
	Contribute to a healthy and diverse river habitat and provides biological corridor linkage to other habitats?	
Safety & Accessibility	Contributes to the ability of the NWC to design reate a safe environment for visitors and pedestrians?	
	Facilitate safe and comfortable access to the river edge and program areas for all visitors?	
Habitat Restoration	is compatible with design solutions that include riparian habitat restoration?	
	Creates adverse impacts relative to the goals USACE Urban Waterways Study?	

The following table compares approximate acreages of the various landscape types within each ROS Alternative, with Alternative 2 highlighted.

Table 5-6:
Landscape Type Areas per Alternative

LANDSCAPE TYPE- RIVERFRONT ALTERNATIVE 2	ACRES *	FLEXIBILITY OF USE
Native Grassland Restoration, Including Water Quality (WQ) Areas WQ Data: WQ acreage = 1.75 Ac WQ volume/capacity = 18.8 Acre Feet (AF). Meets NWC MP requirements.	Up to 5.1	This includes sloping areas not suitable for wetlands/habitat restoration or Festival areas, but are inclusive of WQ areas. This area could be reduced to allow an increase in the quantity of Festival areas, but may limit the amount of WQ capacity accommodated within the ROS and recommended within the NWC Master Plan.
Wetland / Habitat Restoration- Areas Near River Water Level	Up to 0.9	Areas near the river and close to the average water level comprise this category, where wetlands can reasonably be expected to thrive. As the DI will remain in place in Alternative 1, grades between the DI and river banks cannot be significantly changed without impacting the 100-year flood levels. With this in mind, the area in which wetlands/habitat restoration is limited.
Festival Turf Areas- Flat Areas Suitable for Gatherings	Up to 2.3	This designation includes level turfgrass areas that can be used for informal and formal events, which would work well as overflow spaces for events held within the Stockyards. Should structures be planned within the ROS, these flat areas would provide good siting for construction. As the area east of the DI is fixed between the pipes and NW Drive, the amount of space is related to the amount of WQ ponds planned for the area.

**Acreage shown is based on the Alternative 2 plan diagram, and are not prescriptive of a final design. Refer to "FLEXIBILITY OF USE" notes for additional information pertaining to tradeoffs if various landscape types are expanded.*

5.11.3 Riverfront Alternative 3 (Eliminated): In-Situ, Berming Over Existing Pipes

This Alternative aligns with Delgany Alignment A, where the DI pipes remain in place and are “bermed over” in conformance with the NWC Master Plan. Earthen fill would be placed on both sides and on top of the pipes. As can be seen in the red areas within the diagram below, earthwork fill on the river-side of the DI would continue down slope at a 4:1 gradient and, in some instances, fill into the South Platte River channel. As this violates the “no rise in the 100-year floodplain” criteria, compromises the potential for creating a positive river-side experience, and eliminates the possibility of restoring meaningful habitat along the river, this option was eliminated from further consideration.

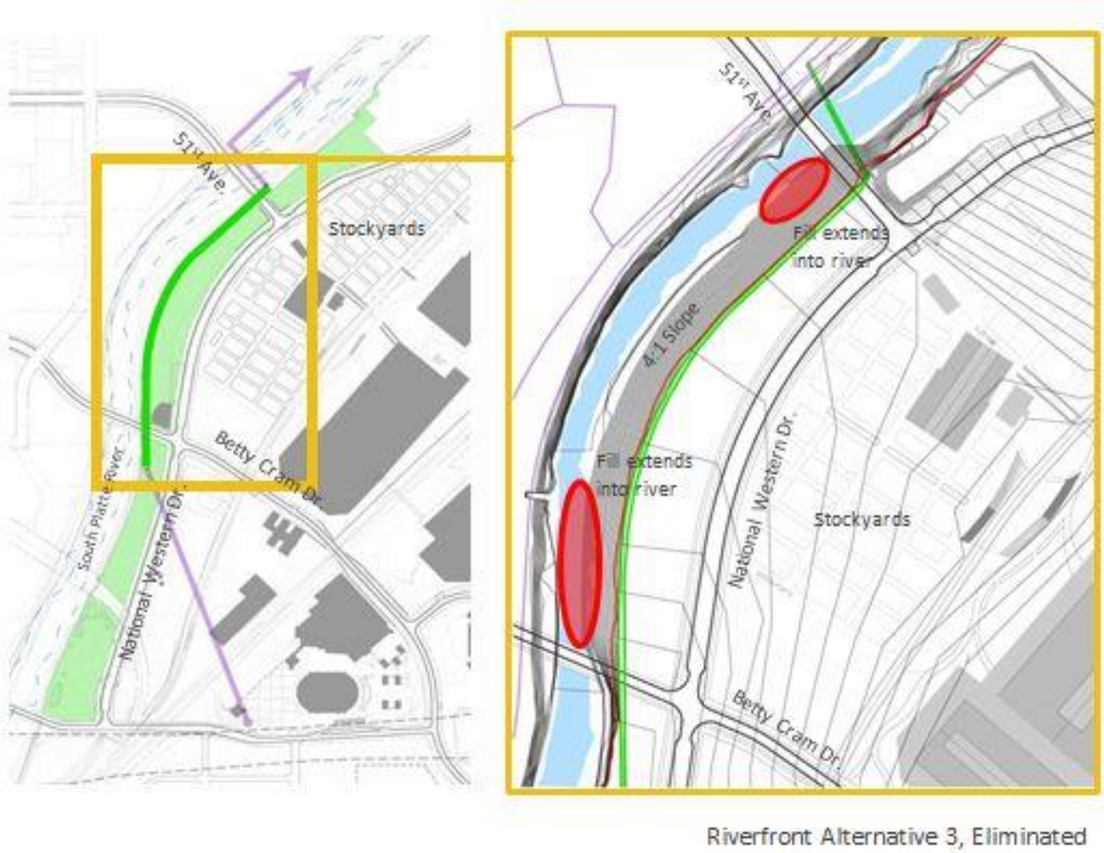


Figure 5-14:
Alternative 3 - Plans

5.11.4 Riverfront Alternative 4: DI Pipes Move Into Open Space, Adjacent to NWD

This Alternative aligns with Delgany Alignment B and includes relocating and burying the DI within the ROS just west of the National Western Drive right of way affords the opportunity to connect pedestrians from NWC to the river by eliminating the current barrier effect of the DI, and by laying back the existing riverbank slopes to ease the actual and perceived isolation when down at the river's edge. Accommodating the water quality pond capacity identified within the NWC Master Plan becomes more difficult in this alternative, as the WQ areas are pushed away from National Western Drive and toward the river, compressing the available space for water quality. The diagram below illustrates the potential of a system of terraced water quality features which would flow from one pond to the next, lower pond, ultimately discharging clearer water back into the river. As the programmable, level areas within the scheme line National Western Drive, the diagram below explores the idea of creating a raised public plaza over and near the river's edge.

A description of the impacts of this alternative is as follows:

- Floodplain Impacts:
    - With the DI relocated, this ROS alternative assumes the steep slopes between the existing DI alignment and the river can be graded back, thereby increasing the cross-

sectional area in which the river can flow. An increase in the 100-year flood elevation does not occur.

- User Experience:
  - With the DI pipes relocated within the ROS and buried, pedestrian flow from the NWC and National Western Drive will be unhindered. Spatial connection of the ROS and the South Platte River will be able to be designed to be barrier free, precluding the need for elevated walks and boardwalks illustrated in Alternatives 1 and 2.
  - Locating the water quality ponds toward the river would allow a more linear and connected festival space (flat open lawn areas) which could be more easily programmed than more separate, discrete spaces in other ROS alternatives.
- Water Quality:
  - Water quality ponds are located between the DI and National Western Drive in Alternatives 1 and 2, as this area is unencumbered with utilities. Relocating the DI within the ROS will require water quality ponds be installed between the DI pipes and the river, as the depth of the pipes will preclude grading ponds above them. Due to sloping grades down to the river, Alternative 4 as illustrated in this report explored terracing water quality ponds to the river's edge. This will require a greater level of design study relative to river flood flows and water quality requirements.
- Safety:
  - With the visual and physical barrier of the DI removed from its present location, unhindered visual connection from the ROS to the river will create a much enhanced sense of connection and safety.
- Habitat Restoration:
  - Once the DI is relocated, the steep existing grades along the river can be eased, with areas along the river graded to create optimum conditions for creation of wetlands and river terraces along the South Platte.
- Cost:
  - While the significant costs of boardwalks and skywalks illustrated in Alternatives 1 and 2 would be avoided, earthwork costs would be greater than those in Alternative 2.

The following exhibits illustrate the site impacts inherent in Riverfront Alternative 4.

Table 5-7:
Alternative 4

Alternative is highly flexible to accommodate programmatic/ qualitative desire | Alternative is modestly flexible to accommodate programmatic/ qualitative desire | Alternative has limited flexibility to accommodate programmatic/ qualitative desire

This matrix illustrates the evaluation of Riverfront Alternative 4. Green checkmarks indicate conformance (yes/no) with stated criteria. Colors indicate level of conformance with qualitiative criteria as described above.

Criteria Title	Criteria Description	Relocated within Open Space 4
Yes/No		
Floodplain Impacts	The riverfront improvements must result in "no rise" to the 100-yr floodplain. Does the alternative meet this requirement (either outright or via mitigation within the NWC project area)?	✓
MWRD Maintenance Access	Does the alternative provide MWRD with necessary/required access to maintain the pipes?	✓
Sewer Heat Recovery	Does the alternative enable the installation of a SHR system, should it be deemed feasible?	✓
General Feasibility	Does the alternative pass the "fatal flaw" test in terms ofother technical feasibility?	✓
Odor Impacts	does not impede odor mitigation?	✓
Qualitative	**How well does the alternative enable the NWC to design a space/amenity that...**	
Master Plan Conformance	creates flat open space that could be used for festivals, events or informal activities, compared to other alternatives?	
	provides flexibility to accommodate MP WQ volumes while maintaining quality of amenity and of program?	
	is compatible with easement and entitlement restrictions on programmatic flexiblity with Riverfront Open Space?	
	provides visitors with varied forms of visual and physical access to the river and to nature?	
	enables connectivity from campus OS within the NWC site to the Riverfront open space?	
	Create places for education and outreach on site related to the Platte River and its watershed through design?	
Sustainability	Help the City reach its 2020 Sustainability goals related to Water Quality?	
	Contribute to a healthy and diverse river habitat and provides biological corridor linkage to other habitats?	
Safety & Accessibility	Contributes to the ability of the NWC to design reate a safe environment for visitors and pedestrians?	
	Facilitate safe and comfortable access to the river edge and program areas for all visitors?	
Habitat Restoration	is compatible with design solutions that include riparian habitat restoration?	
	Creates adverse impacts relative to the goals USACE Urban Waterways Study?	

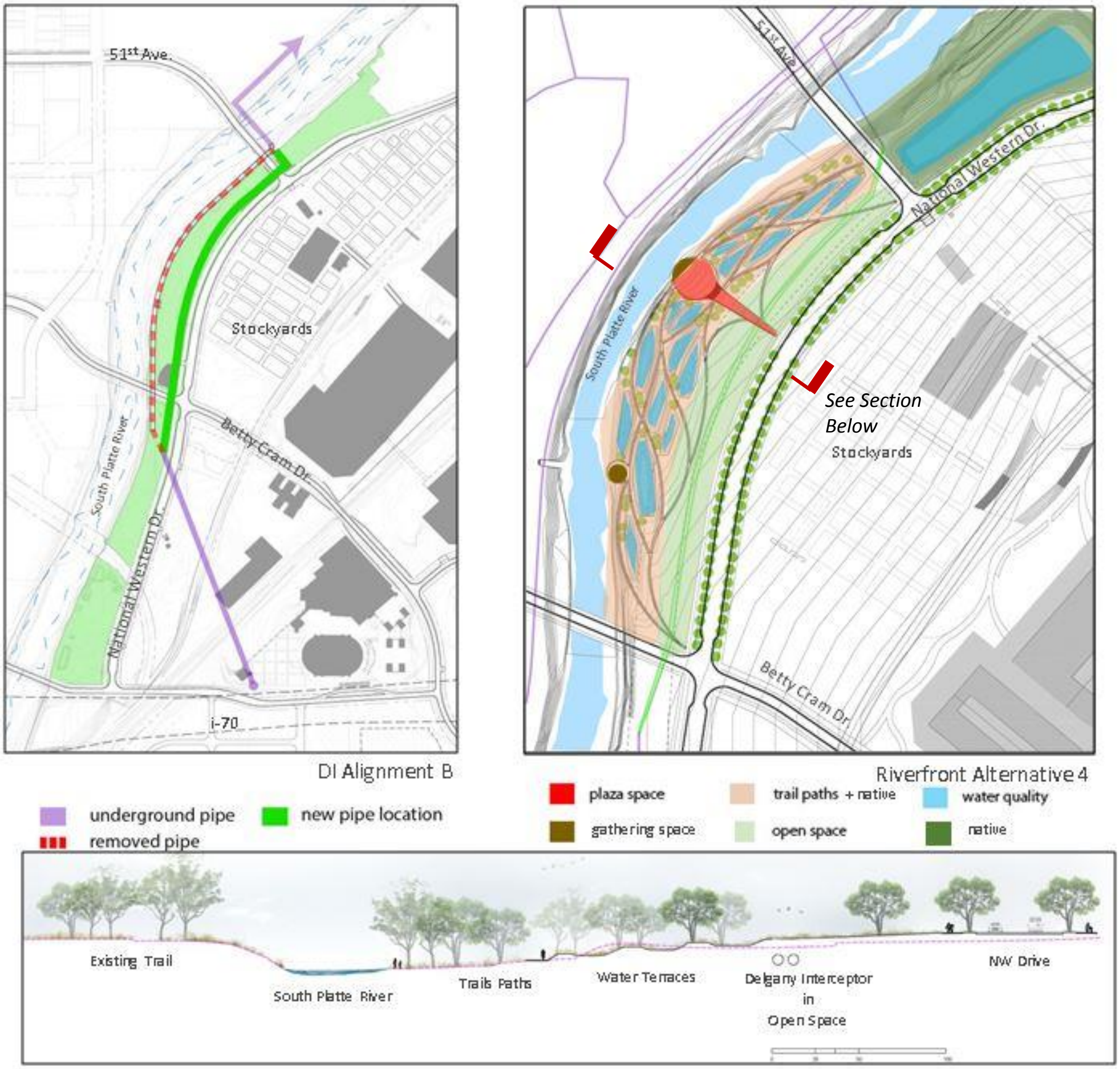
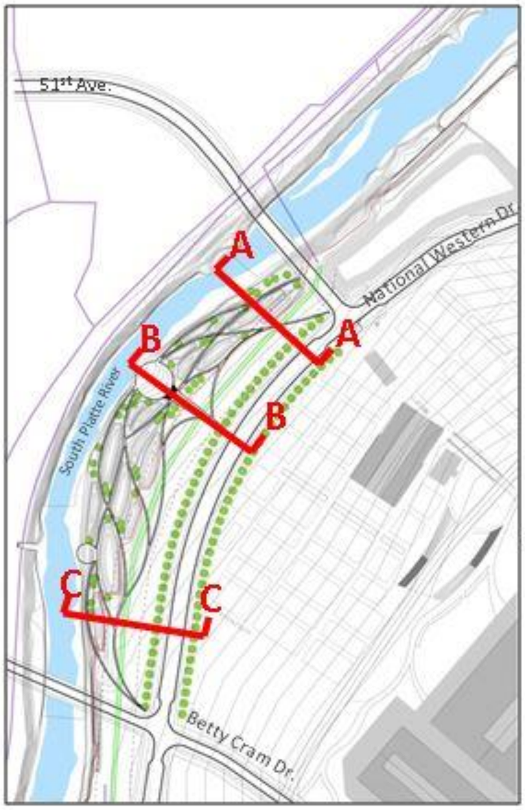
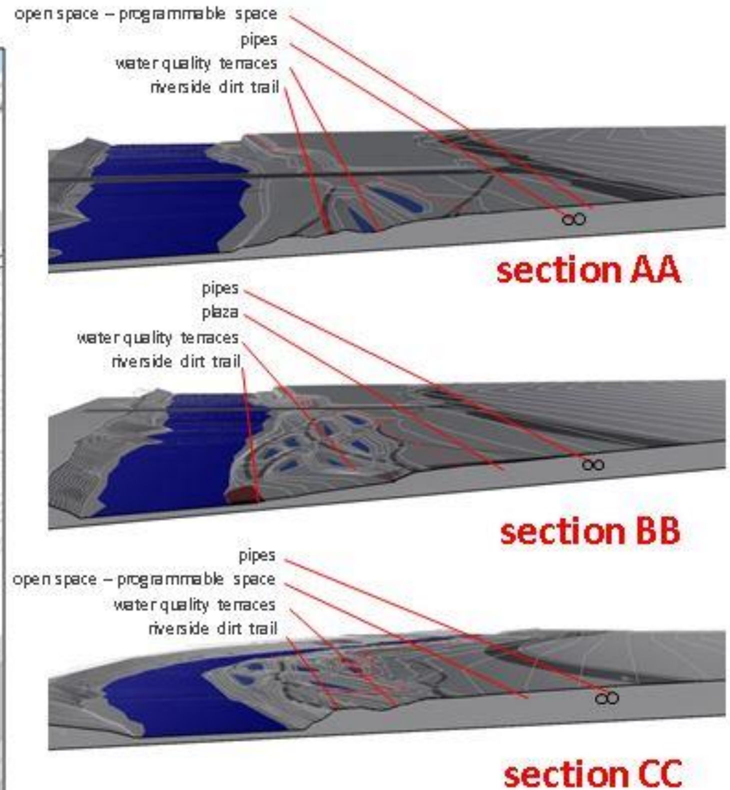


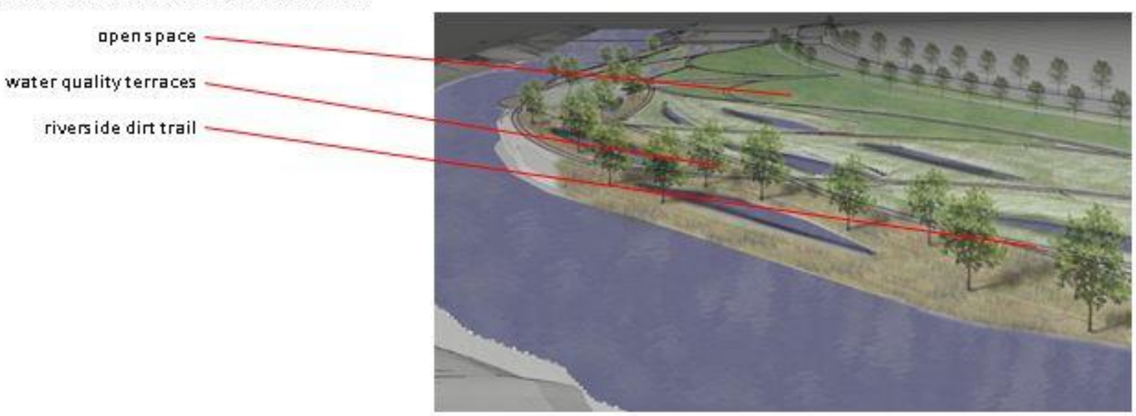
Figure 5-15:
Alternative 4 Plans and Section

The section above illustrates the sitework potential with the DI relocated and buried to the east, within the ROS. This unlocks the ability to grade the existing slopes near the river back to create a smoother and more accessible transition from the NWC and ROS to the river's edge. The location of the DI makes placing water quality ponds atop the pipes more difficult, as the pond bottoms may expose the DI. In response, this alternative moves the WQ ponds to further west, terracing them down the hill. Stormwater would flow from one to the next lower pond, cleansing water prior to going in to the river. This also allows greater flexibility in habitat restoration, as grades near the river can be eased to create wetlands and river terraces.



Riverfront Alternative 4: Section Cut Locations





Riverfront Alternative 4: Perspective Looking North

Figure 5-16:
Alternative 4 Plan, Sections and Perspective

Riverfront Alternative 3: Inspirational Imagery- Terraced Landforms, Waterfront Plaza, Wetland Terraces

Figure 5-17:
Alternative 4 Landscape Concepts

Table 5-8:
Alternative 4 Evaluation Criteria

This matrix illustrates the evaluation of Riverfront Alt 1. Green checkmarks indicate conformance (yes/no) with stated criteria. Colors indicate level of conformance with qualitative criteria.

Criteria Title	Criteria Description	Relocated within Open Space 4
Gating/Yes-No		
Floodplain Impacts	The riverfront improvements must result in "no rise" to the 100-yr floodplain. Does the alternative meet this requirement (either outright or via mitigation within the NWC project area)?	TBD
MWRD Maintenance Access	Does the alternative provide MWRD with necessary/required access to maintain the pipes?	✓
Sewer Heat Recovery	Does the alternative enable the installation of a SHR system, should it be deemed feasible?	✓
General Feasibility	Does the alternative pass the "fatal flaw" test in terms of other technical feasibility?	✓

The following table compares approximate acreages of the various landscape types within each ROS Alternative, with Alternative 4 highlighted.

Table 5-9:
Landscape Type Areas per Alternative

LANDSCAPE TYPE-RIVERFRONT ALTERNATIVE 4	ACRES *	FLEXIBILITY OF USE
Native Grassland Restoration, Including Water Quality (WQ) Areas <u>WQ Data:</u> WQ acreage = 1.80 Ac WQ volume/capacity = 18.95 Acre Feet. Exceeds NWC MP requirements.	Up to 4.0	This includes sloping areas not suitable for wetlands/habitat restoration or Festival areas, but are inclusive of WQ areas. Rather than a few large WQ ponds as in the NWC Master Plan and in Alternatives 1,2 and 5, Alternative 4 assumes that WQ ponds are separated into a series of terraces. While less efficient from a WQ standpoint, this approach visually knits the WQ facilities more with the native landscape. This approach could be modified and this area could be reduced to allow an increase wetlands/habitat restoration and/or Festival areas. This may limit the amount of WQ capacity accommodated within the ROS and recommended within the NWC Master Plan.
Wetland / Habitat Restoration- Areas Near River Water Level	Up to 1.0	Areas near the river and close to the average water level comprise this category, where wetlands can reasonably be expected to thrive. This area could be expanded by pushing bank grades to the east to create more level area near the river bank. However, impacts would include 1) Slopes/banks to the east may be steepened, negatively impacting pedestrian access to the river; 2) Native grassland restoration areas would likely be reduced, potentially reducing the amount of WQ capacity accommodated within the ROS; 3) Festival areas would likely be reduced, lessening the flexibility to hold events within the ROS. A more consolidated approach to WQ could also minimize the footprint of the WQ area, allowing more allocation of area to native grassland and festival/turf areas.
Festival Turf Areas- Flat Areas Suitable for Gaterings	Up to 3.3	This designation includes level turfgrass areas that can be used for informal and formal events, which would work well as overflow spaces for events held within the Stockyards. Should structures be planned within the ROS, these flat areas would provide good siting for construction. The Festival areas could be reduced to allow for more wetlands/habitat restoration area and/or additional area for native grassland restoration. The associated negative impact would be to reduce the flexibility of uses within the ROS and limit the ability of the ROS to host events. To gain additional festival/event area, expanding this zone may be considered, which may steepen the riverbank and/or constrain the wetlands/habitat restoration area. Any impact to the riverbank slope must be modeled to assure that a rise in the South Platte's 100-year flood level is not caused.

**Acreage shown is based on the Alternative 4 plan diagram, and are not prescriptive of a final design. Refer to "FLEXIBILITY OF USE" notes for additional information pertaining to tradeoffs if various landscape types are expanded.*

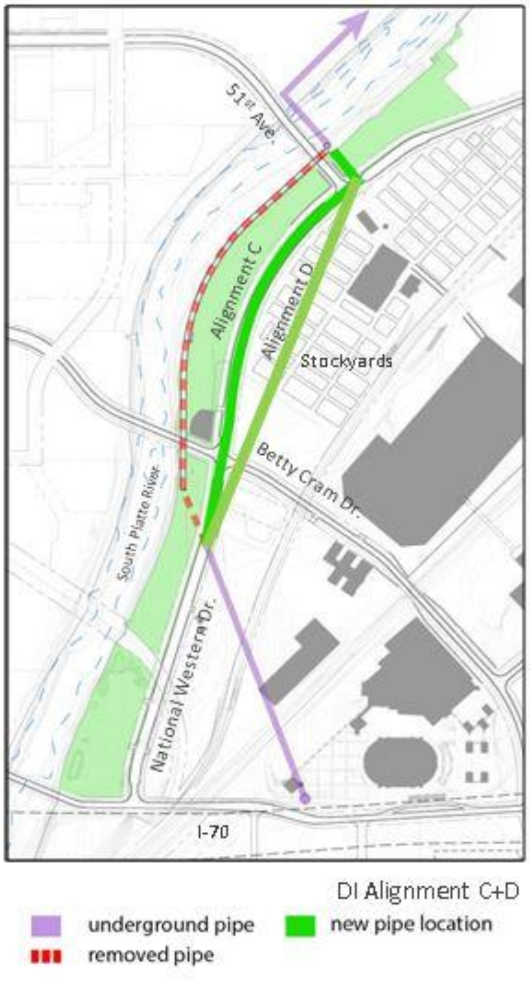
5.11.5 Riverfront Alternative 5: Move Pipes Out of the Riverfront Open Space

This Alternative aligns with Delgany Alignments C, D and E, where the DI pipes are relocated out of the Riverfront Open Space area, potentially within the National Western Drive ROW or another location east of the ROS. While presenting challenges from a pipe routing perspective, this Alternative provides for maximum open space design and programming flexibility. Existing slopes near the river could be laid back, creating greatly improved pedestrian access to the water's edge, and giving increased flexibility in locating water quality ponds within the ROS. As riverbank slopes can be laid back, additional programmatic possibilities come in to play, including a riverfront amphitheater. Habitat restoration options are also increased by creating gentler sloped areas near the river.

The impacts of this alternative are described as follows:

- Floodplain Impacts:
    - With the DI relocated, this ROS alternative assumes the steep slopes between the existing DI alignment and the river can be graded back, thereby increasing the cross-sectional area in which the river can flow. An increase of the 100-year flood elevation does not occur.
- User Experience:
    - With the DI pipes relocated within the ROS and buried, pedestrian flow from the NWC and National Western Drive will be unhindered. Spatial connection of the ROS and the South Platte River will be able to be designed to be barrier free, precluding the need for elevated walks and boardwalks illustrated in Alternatives 1 and 2.
- Water Quality:
    - This alternative would not hinder the NWC's ability to provide water quality facilities per the NWC Master Plan.
- Safety:
    - With the visual and physical barrier of the DI removed from its present location, unhindered visual connection from the ROS to the river will create a much enhanced sense of connection and safety.
- Habitat Restoration:
    - Once the DI is relocated, the steep existing grades along the river can be eased, with areas along the river graded to create optimum conditions for creation of wetlands and river terraces along the South Platte.
    - This alternative illustrates an amphitheater/gathering space. Further design study is needed to balance the need for such a space with its impact on the riverside experience and habitat restoration.
- Cost:
    - While the significant costs of boardwalks and skywalks illustrated in Alternatives 1 and 2 would be avoided, earthwork costs would be greater than those in Alternative 2.

The following exhibits illustrate the site opportunities inherent in Riverfront Alternative 5.



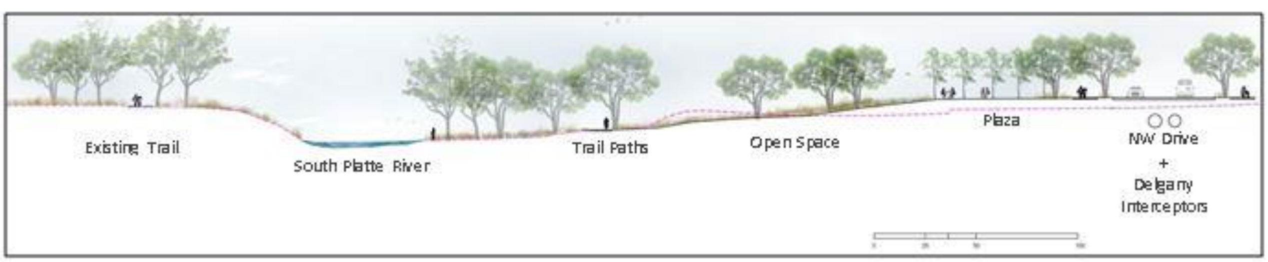
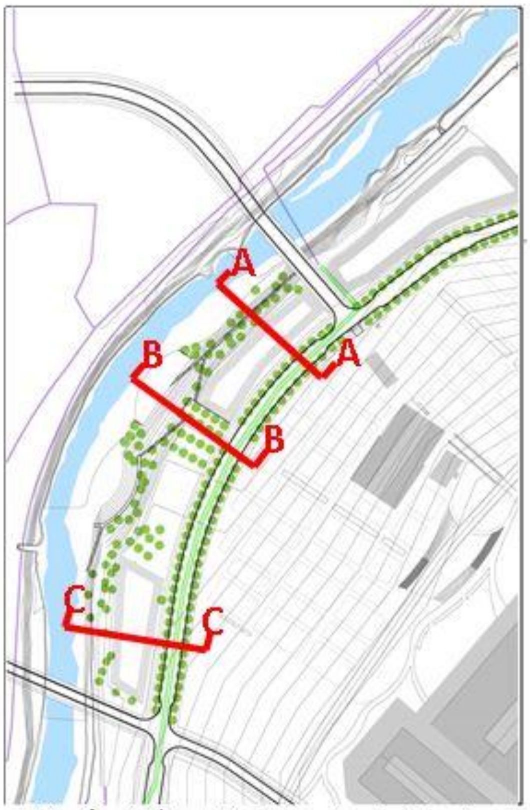
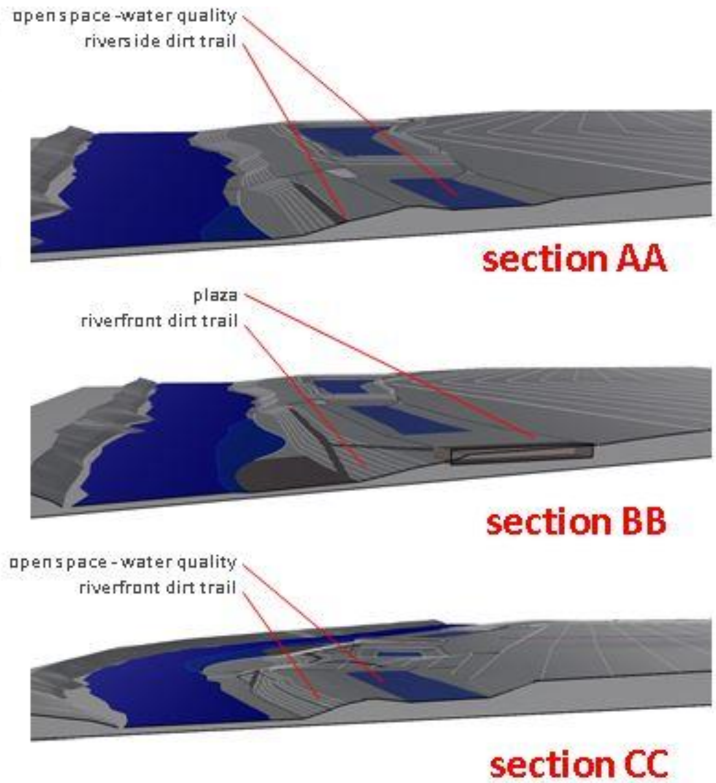


Figure 5-18:
Alternative 5 – Plans and Section

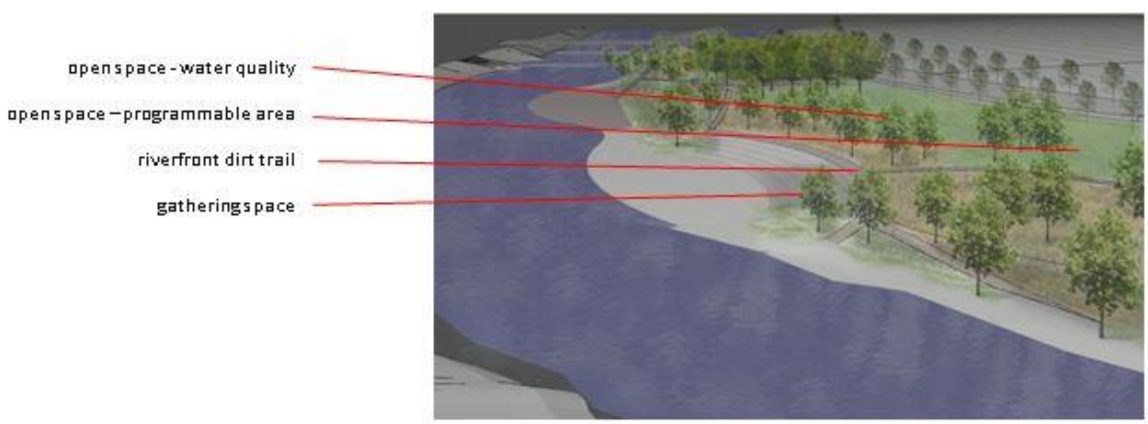
The above section of Alternative 5 illustrates the flexibility of open space design when the DI is relocated completely out of the ROS. Grade modifications can be totally related to programmatic desires for habitat restoration and the provision of flat, programmable areas that can be used for festivals, open field informal play, or as adjunct space for events occurring within the Stockyards. Near the river, dirt paths, places to sit and rest, and viewing terraces can be provided. The diagram above shows a gathering place near the river, which could be a landscape-oriented amphitheater similar to the photo below. Any development closer to the river will need to be evaluated relative to flood levels and impacts to potential habitat restoration.



Riverfront Alternative 5: Section Cut Locations



Section Perspectives



Riverfront Alternative 5: Perspective Looking North

Figure 5-19:
Alternative 5 – Plan, Sections and Perspective

Riverfront Alternative 4: Inspirational Imagery- Amphitheater, Soft Paths, Building/Terrace

Figure 5-20:
Alternative 4 Landscape Concepts

Table 5-10:
Alternative 5 Evaluation Criteria

Alternative is highly flexible to accommodate programmatic/ | Alternative is modestly flexible to accommodate programmatic/ | Alternative has limited flexibility to accommodate programmatic/

Criteria Title	Criteria Description	Relocated out of Open Space 5
	This matrix illustrrates the evaluation of Riverfront Alternative 5. Green checkmarks indicate conformance (yes/no) with stated criteria. Colors indicate level of conformance with qualitiative criteria as described above.	
Yes/No		
Floodplain Impacts	The riverfront improvements must result in "no rise" to the 100-yr floodplain. Does the alternative meet this requirement (either outright or via mitigation within the NWC project area)?	✓
MWRD Maintenance Access	Does the alternative provide MWRD with necessary/required access to maintain the pipes?	✓
Sewer Heat Recovery	Does the alternative enable the installation of a SHR system, should it be deemed feasible?	✓
General Feasibility	Does the alternative pass the "fatal flaw" test in terms ofother technical feasibility?	✓
Odor Impacts	does not impede odor mitigation?	✓
Qualitative	**How well does the alternative enable the NWC to design a space/amenity that…**	
Master Plan Conformance	creates flat open space that could be used for festivals, events or informal activities, compared to other alternatives?	
	provides flexibility to accommodate MP WQ volumes while maintaining quality of amenity and of program?	
	is compatible with easement and entitlement restrictions on programmatic flexiblity with Riverfront Open Space?	
	provides visitors with varied forms of visual and physical access to the river and to nature?	
	enables connectivity from campus OS within the NWC site to the Riverfront open space?	
	Create places for education and outreach on site related to the Platte River and its watershed through design?	
Sustainability	Help the City reach its 2020 Sustainability goals related to Water Quality?	
	Contribute to a healthy and diverse river habitat and provides biological corridor linkage to other habitats?	
Safety & Accessibility	Contributes to the ability of the NWC to design reate a safe environment for visitors and pedestrians?	
	Facilitate safe and comfortable access to the river edge and program areas for all visitors?	
Habitat Restoration	is compatible with design solutions that include riparian habitat restoration?	
	Creates adverse impacts relative to the goals USACE Urban Waterways Study?	

The following table compares approximate acreages of the various landscape types within each ROS Alternative, with Alternative 5 highlighted.

Table 5-11:
Landscape Type Areas per Alternative

LANDSCAPE TYPE-RIVERFRONT ALTERNATIVE 5	ACRES *	FLEXIBILITY OF USE
Native Grassland Restoration, Including Water Quality (WQ) Areas WQ Data: WQ acreage = 1.75 Ac WQ volume/capacity = 18.8 Acre Feet (AF). Meets NWC MP requirements.	Up to 5.2	This includes sloping areas not suitable for wetlands/habitat restoration or Festival areas, but are inclusive of WQ areas. This area could be reduced to allow an increase wetlands/habitat restoration and/or Festival areas, but may limit the amount of WQ capacity accommodated within the ROS and recommended within the NWC Master Plan.
Wetland / Habitat Restoration-Areas Near River Water Level	Up to 1.2	This alternative has the gretest amount of flexibility to increase habitat along the river. The diagram associated with this alternative shows grades laid back more gently, emphasizing pedestrian connections to the river. This has the impact of reducing the flat areas near the river. However, this area could be expanded by pushing bank grades to the east to create more level area near the river bank. However, impacts would include 1) Slopes/banks to the east may be steepened, impacting pedestrian access to the river; 2) Native grassland restoration areas would likely be reduced, potentially reducing the amount of WQ capacity accommodated within the ROS; 3) Festival areas would likely be reduced, lessening the flexibility to hold events within the ROS.
Festival Turf Areas- Flat Areas Suitable for Gaterings	Up to 1.9	This designation includes level turfgrass areas that can be used for informal and formal events, which would work well as overflow spaces for events held within the Stockyards. Should structures be planned within the ROS, these flat areas would provide good siting for construction. The Festival areas could be reduced to allow for more wetlands/habitat restoration area and/or additional area for native grassland restoration. The associated negative impact would be to reduce the flexibility of uses within the ROS and limit the ability of the ROS to host events. Should additional festival/event area be desired, expanding this zone may be considered, which would steepen the riverbank and/or constrain the wetlands/habitat restoration area. Any impact to the riverbank slope must be modeled to assure that a rise in the South Platte's 100-year flood level is not caused.

**Acreage shown is based on the Alternative 5 plan diagram, and are not prescriptive of a final design. Refer to "FLEXIBILITY OF USE" notes for additional information pertaining to tradeoffs if various landscape types are expanded.*

Table 5-12:
WQ Capacity

	NWC Master Plan WQ (AF) Capacity	WQ Included in Alternative Diagram (AF)	Difference
Alternative 1	18.8	18.8	0.0
Alternative 2	18.8	18.8	0.0
Alternative 4	18.8	18.94	0.1
Alternative 5	18.8	18.8	0.0

Each of the three analyses performed in this Study are interrelated and were closely coordinated with each other. With regard to the implementation of recommendations for each analysis, however, it is understood that Sewer Heat Recovery may be pursued independent of any decision related to relocating the DI pipes. The recommendations presented herein address each analysis independently, with some caveats regarding the scheduling of each program relative to the others.

6.1 DELGANY INTERCEPTOR ALIGNMENT ANALYSES

The technical analysis completed in the study confirmed that the DI pipes can be relocated to other locations on the NWC Campus. Development of the full potential of Riverfront Open Space at NWC, and fulfillment of many of the NWC guiding principles, can be most readily accomplished through the removal of the existing aboveground Delgany Interceptor and replacing it with new, buried interceptor pipes within the new, proposed National Western Drive (Alignment C). The relocation of Delgany Interceptor to Alignment C provides the broadest range of opportunities for implementing Riverfront Open Space improvements, with only minimal disadvantages. The other alignment option for relocating DI, which involves relocation of the Delgany Interceptor to an alignment across Open Space (Alignment B) could also fulfill the guiding principles, but this alignment has other, more significant disadvantages and limitations on fulfilling all of the Master Plan guidelines. It is recommended that the DI be relocated to Alignment C.

6.2 SHR SCREENING ANALYSES

Based on the analysis of thermal energy available in the Delgany interceptor, there is an opportunity to make use of the Delgany interceptor for heating and cooling at the NWC. There appears to be sufficient thermal energy supply to operate a SHR system with heat pumps to meet the heating demands for the buildings contemplated at the NWC. Similarly, there is capacity in the Delgany interceptor to provide cooling in a district system for the NWC, with waste heat being rejected back in to the Delgany interceptor in the summer time.

To meet the thermal energy demands at the NWC, the campus would require the use of a district energy system using heat pumps and a distribution loop to provide heating and cooling for individual buildings within the NWC. Examples of SHR systems indicate that SHR systems can be cost-effective and have the potential to reduce the electricity and natural gas used to provide domestic hot water heating and space heating in the buildings, while at the same time reducing the sewage temperature in the Delgany interceptor.

If the NWC is contemplating the use of innovative technologies, it is recommended that further analysis and design development be undertaken to evaluate and refine the sizing of the SHR system in combination with thermal storage. The annual and peak heating and cooling demands for individual buildings should also be refined and confirmed at the design stage.

Screening criteria have been developed to assist in the evaluation of the potential for SHR and it is recommended that the screening analysis be conducted for each of the identified scenarios to confirm the scope and feasibility of SHR at the NWC.

The development of Sewer Heat Recovery at NWC could provide an economically viable renewable energy source that could reasonably satisfy approximately 70% of the heating and cooling energy demands at the NWC. The relocation of the Delgany Interceptor, along with the planning and design of new, centralized heating and cooling facilities to serve the NWC provide a unique and timely opportunity to implement Sewer Heat Recovery.

6.3 SOUTH PLATTE RIVERFRONT CONCEPTS

Development of Riverfront Open Space at NWC and fulfillment of many of the NWC guiding principles can be accomplished to varying degrees depending on the final determination of the preferred alignment of the DI. This Study provides quantified data and subjective considerations intended to allow an informed decision by the NWCO in selection of a DI Alignment, and the associated Riverfront Open Space Alternative.

If it is determined that there is a preferred alternative for redevelopment of the Riverfront Open Space, then this preference and decision should be coordinated with the selection of the DI alignment to assure that the new DI alignment will not be an obstacle to the preferred Riverfront Open Space concept.

6.4 CONSTRUCTION PHASING AND SCHEDULE

The NWC Master Plan states that design and construction of Phases 1 and 2 are planned for implementation over the next 10 years. The South Platte Riverfront area, within the NWC, is identified in the NWC phasing plan as part of Phase 1, as shown in Figure 6-1.

The ultimate phasing of the project will depend on a variety of factors. This Plan identifies one possible phasing alternative.

Figure 6-1:
Project Phasing Map

The implementation of the Phase 1 improvements for the NWC site can proceed immediately following the selection of a preferred Delgany Interceptor alignment option and Riverfront Development Concept. An apparent critical path issue for the Phase 1 implementation plan is the procurement and completion of design and construction to relocate the Delgany Interceptor. If the Phase 1 program includes relocation of the Delgany Interceptor, it is recommended that the new interceptor pipes should be installed, and the existing Delgany Interceptor pipes removed and disposed prior to the initiation of the improvements for the Riverfront Open Space Development. This recommendation is based on construction cost and constructability issues that will become more complex if the relocation of the Delgany Interceptor is not completed prior to Riverfront Open Space Development.

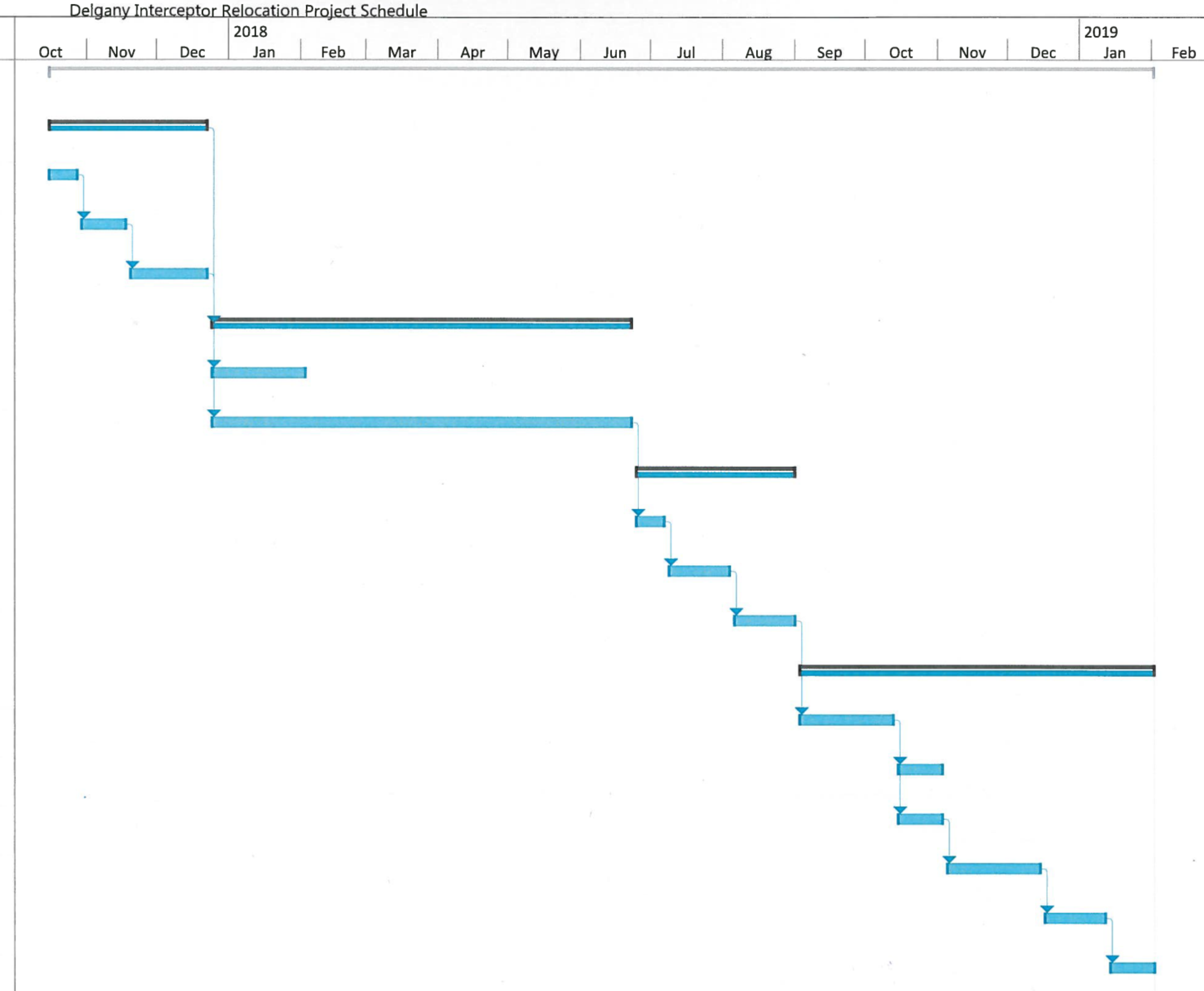
The construction schedule for the Delgany Interceptor relocation must be closely coordinated with MWRD operations and maintenance activities. Construction costs and complexity could increase significantly if the tie-in connections of the new Delgany pipes to the existing Delgany infrastructure are not planned to take advantage of periods of reduced Delgany Interceptor wastewater flows, groundwater conditions, and weather conditions. Additionally, continuous MWRD access to the existing Delgany Interceptor must be accommodated throughout the construction of the new Delgany pipes.

A proposed project schedule for the design and construction of a new Delgany Interceptor is shown in Figure 6-2 on the following page. The schedule is based on a typical Design-Bid-Build approach to the project, and assumes that the selection of an alignment and the decision to proceed will be completed prior to October 2018. The project duration for the Delgany Interceptor is estimated to be approximately 17 months. The timing of this decision and the progress of the design and construction bidding and procurement could be advantageous in that the Delgany wet connection tie-ins would occur at an ideal time, in the Winter of 2018. The feasibility of this schedule is highly dependent on the site availability, and assumes that the existing rail spur adjacent to the future National Western Drive has been relocated. This proposed schedule must be re-visited if the rail spur re-location is not accomplished prior to the start of the DI pipes construction.

Implementation of the SHR and Riverfront Open Space improvements must be coordinated with their respective programs within the overall NWC redevelopment program. Design-bid-build durations for each of these programs are estimated to be significantly greater than the DI project, with an estimated total duration of 30 months. The extended durations are due to additional time needed for design and permitting, and for equipment procurement.

Delgany Interceptor Relocation Project Schedule

ID	Task Name	Duration	Start	Finish
0	**Delgany Relocation**	**340 days**	**Mon 10/16/17**	**Fri 2/1/19**
1	**Procure Engineering Services**	**10 wks**	**Mon 10/16/17**	**Fri 12/22/17**
2	Prepare RFP	2 wks	Mon 10/16/17	Fri 10/27/17
3	Engineering Proposals	3 wks	Mon 10/30/17	Fri 11/17/17
4	Review Proposals/Select Engineer/Contract Award	5 wks	Mon 11/20/17	Fri 12/22/17
5	**Design Engineering**	**26 wks**	**Mon 12/25/17**	**Fri 6/22/18**
6	Geotech Investigations	6 wks	Mon 12/25/17	Fri 2/2/18
7	Design	26 wks	Mon 12/25/17	Fri 6/22/18
8	**Construction Bidding**	**10 wks**	**Mon 6/25/18**	**Fri 8/31/18**
9	Advertise/Site Walk	2 wks	Mon 6/25/18	Fri 7/6/18
10	Contractor Proposals	4 wks	Mon 7/9/18	Fri 8/3/18
11	Bid Review/Contract Award	4 wks	Mon 8/6/18	Fri 8/31/18
12	**Construction**	**22 wks**	**Mon 9/3/18**	**Fri 2/1/19**
13	Mobilization/Material Procurement	6 wks	Mon 9/3/18	Fri 10/12/18
14	Install 3800 LF 60" Pipe	3 wks	Mon 10/15/18	Fri 11/2/18
15	Siphon Demolition	3 wks	Mon 10/15/18	Fri 11/2/18
16	Wet Tie-in Connections	6 wks	Mon 11/5/18	Fri 12/14/18
17	Demolition-3800 LF 72"/78' Pipe	4 wks	Mon 12/17/18	Fri 1/11/19
18	Demobilization	3 wks	Mon 1/14/19	Fri 2/1/19



Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline			
Split	External Tasks	Inactive Summary	Manual Summary	Progress			
Milestone	External Milestone	Manual Task	Start-only	Manual Progress			
Summary	Inactive Task	Duration-only	Finish-only				

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Figure 6-2:
Project Schedule

Appendix A

Historic Maps And Property Agreements

Appendix B

Hydraulic Analysis Existing Delgany Interceptor

Appendix C

Sewer Heat Recovery Case Studies