Route Selection Based on a Weighted Ranking Analysis

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ABSTRACT

Route selection is a critical process in the preliminary design of linear infrastructure. A weighted ranking analysis of pipeline routes allows for the selection of a project alignment that results in the lowest overall impact based on project-specific variables. Factors that influence and inform a routing analysis can be categorized and subcategorized into project-specific evaluation criteria. Examples of pipeline routing evaluation criteria are environmental impacts, financial impacts, and social impacts. Each of these criteria can contain one or more site specific subcategories such as right of way/easement requirements, cost, utility impacts, cultural/archeological historical impacts, or other named issues of stakeholder importance. An initial screening of potential routes is generally performed to lay the groundwork for a more detailed evaluation. Multiple routes are developed, less attractive routes are eliminated, and the routes that remain after the initial screening process are evaluated using a weighted ranking analysis. Evaluation criteria are given a score based on their relative importance to one another, the criteria are quantified by level of impact, then weighted based on project-specific conditions. The evaluation method will vary depending on the type of project and should be modified as necessary depending on the goals and interests of the owner. The scoring matrix ultimately generates a ranked list of pipeline routes that range from least impactful to most impactful and allows an engineer to recommend a pipeline route with supporting justification. This technical paper will present an alternative pipeline routes case study, show how evaluation criteria influence the scoring of each route, and show how an optimal route is selected based on a weighted ranking analysis. The weighted ranking system will show how the project owner's goals and interests affect the route selection process (i.e. critical project goals are weighted according to importance), and how this type of analysis can be used to justify a route recommendation. This type of route analysis is both qualitative and quantitative, ultimately providing a source of justification for a critical preliminary design element of pipeline projects.

INTRODUCTION

Route selection is a critical process in the preliminary design of linear infrastructure. This decision point defines the parameters by which the project stakeholders must work within for all future stages of design. As is typical for most efforts, preliminary planning is critical for the ultimate quality and efficiency of the project.

A weighted ranking analysis of pipeline routes begins by developing a list of project-specific variables that can influence the outcome and success of the project. Variables that are most relevant and have the most potential to influence the alignment are selected for the analysis. An initial screening process defines multiple alignments, these alternatives are narrowed down through a preliminary filter (typically a Geographic Information System (GIS) based approach), and then scored/ranked based on the project needs.

A weighting factor is assigned to each of the project-specific variables. The impacts of each variable and its associated weighting factor is then used to calculate the impacts on the pipeline route. Impacts are relative to one another, as defined by the weighting factor. For example, a rural land use might be a positive impact if the alternative route traverses a highly developed area. Alternatively, a negative impact might represent itself as a particularly difficult crossing that might require tunneling or other trenchless pipeline installation techniques, while an alternative route can be traversed using open cut installation.

A weighted ranking analysis provides both a qualitative and quantitative approach, allowing for the stakeholders to prioritize goals and interests which are then reflected in the weighted scoring system. The multiple alignments are ranked according to the cumulative impact of the influencing factors, and a final route recommendation can be made with associated justification for the final selection of a route.

ROUTE SELECTION GENERAL METHODOLOGY

The route selection process typically is initiated by defining a broad area between fixed end conditions, typically a starting point, and ending point, and sometimes intermediate points. Relevant data can then be obtained within that area. A GIS-based approach allows for both public and private sources of information, depending on the goals of the project and the interests of the stakeholder(s). GIS data is selected and obtained based on criteria that could hypothetically impact any of the project disciplines/stakeholders (e.g. owners, public agencies, engineers, right of way specialists, environmental scientists, surveyors, construction specialists). GIS-based information can be readily obtained from publicly available sources; the following sample of data represents examples of publicly downloadable information:

- Recent aerial photography
- Land use mapping and designations
- Tax maps and associated parcel/landowner information
- Existing utilities that parallel or cross the project area
- Road, railroad and water crossings
- Jurisdictional boundaries of states, counties, cities
- Federal and state threatened and endangered species
- Wetlands and other environmentally sensitive properties
- Soils and other geotechnical information

A site visit is an essential companion to the desktop study/mapping outlined above. For shorter pipeline alignments, walking the route while taking notes and pictures is an effective way to document existing conditions and record personal knowledge of the environment. Longer alignments can be driven, especially where alignments parallel roads; even longer or less accessible alignments may require the use of aerial flyovers (e.g. drones, helicopter) to cover significant distances. GPS capable cameras are a good tool to document the location and condition of a certain area. Web-based aerial and street level mapping also provides a useful source of information, as it is often the case that pipelines are not located in publicly accessible/visible locations. The following is a case study that presents this weighted ranking analysis approach.

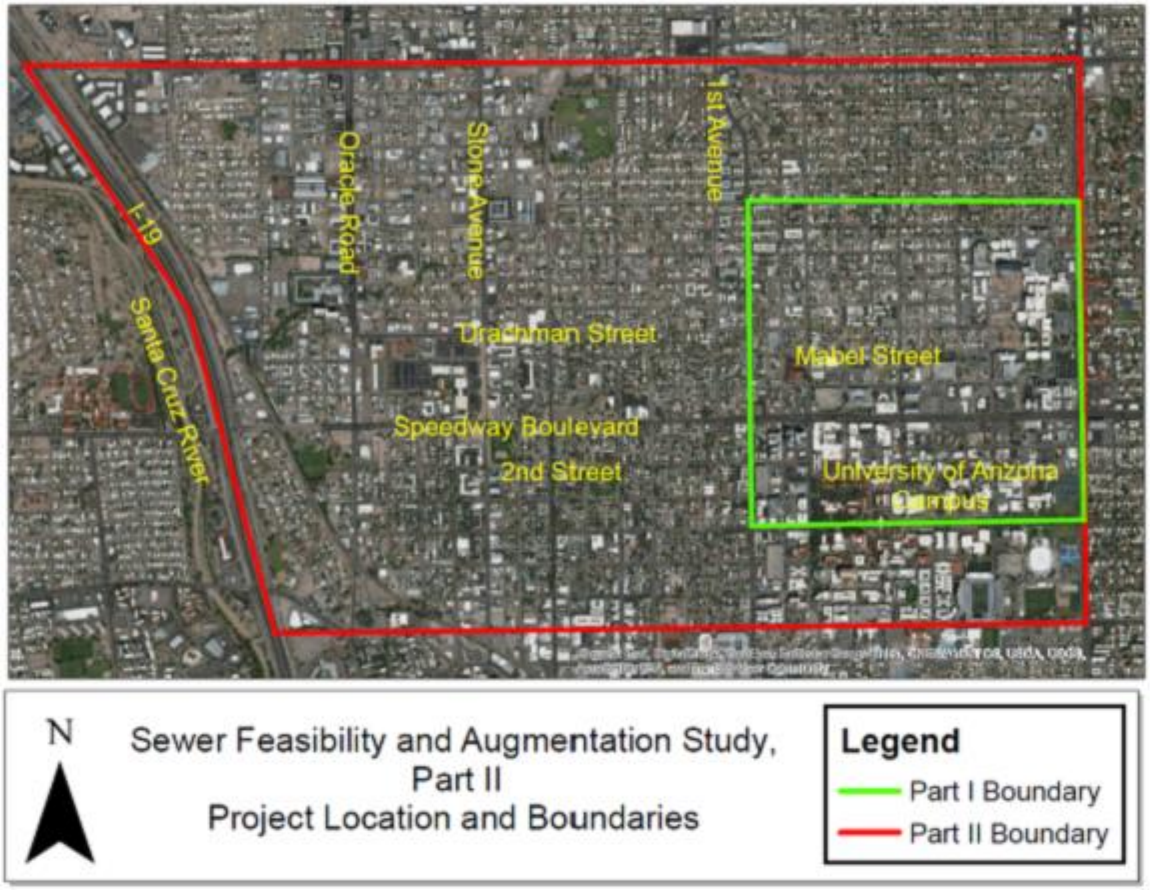

Figure 1. Part II Sewer Feasibility and Alignment Study Downstream Boundaries

CASE STUDY

Pima County Regional Wastewater Reclamation Department (RWRD) has identified that the area in and around the University of Arizona (UofA) is experiencing significant growth with potential increases in sanitary sewer discharges that may exceed the capacity of the sewer trunk lines much of which date to the early 1900's. In May of 2013, Stantec Consulting Services Inc. (Stantec) issued a report to the RWRD for the Sewer Feasibility and Alignment Study for University of Arizona Area Augmentation (Part I). This report was the culmination of an effort to evaluate the increase in sanitary sewer discharges from the UofA area as the result of planned high density residential and commercial development and its potential to exceed the peak flow capacity of the existing sewer trunk lines. For the purposes of this study, the UofA was defined as an area delineated by Linden Street to the north and University Boulevard to the south between Euclid Avenue and Campbell Avenue (see Figure 1). Within these boundaries the study identified seven sewersheds out of which three were selected, using combined existing and calculated build-out sewer flows, as having a potential for peak capacity exceedance. The sewersheds identified as at risk for peak capacity exceedance in Part I highlighted the need for further study downstream of the initial study area for future system augmentation needed to capture the larger flows.

Stantec's hydraulic analysis showed the need for increased pipe capacity in the Part I sewersheds of Warren Avenue, Drachman Street, and 2nd Street. However, the existing sewer lines immediately downstream of the study boundaries are the same size for these sewersheds as within the study boundaries. Made aware of this issue, PCRWRD asked Stantec to investigate sewer augmentation downstream of the original study boundaries, determine the downstream limits needed for augmentation, and recommend the preferred routing for increased sewer capacity (see **Figure 1**). Referred to as Part II of this study it included a sewer system evaluation in an expanded area approximately three times larger than the Part I study.

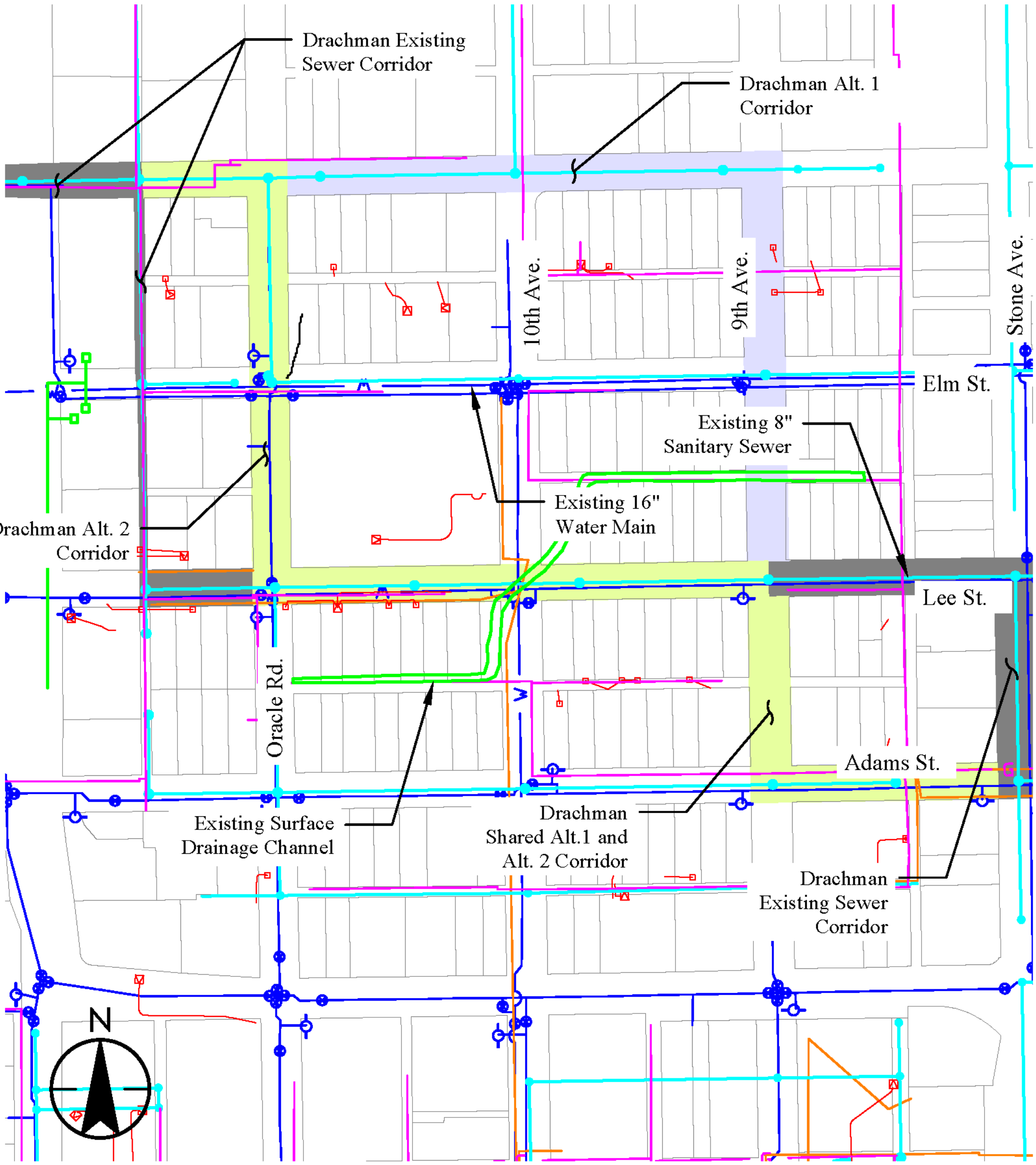

Figure 2. Drachman Route 1 and Alternatives 1 and 2

After the expanded hydraulic modeling downstream of this area was conducted by Stantec, it was determined that the Warren Avenue sewershed could be removed from the under-capacity list and three hydraulic alternatives for augmentation emerged. It is from these alternatives that the main augmentation routes were identified, and the subsequent alternative routes vetted. The Drachman Sewershed is one area that emerged as a target for augmentation where several alternative routes for sewer augmentation were available. This sewershed serves a high-density mixed-use urban area in the City of Tucson stretching from the UofA to an area just north of downtown.

ROUTE AND ALTERNATIVES

The Drachman sewershed is so named because its path follows that street westbound out of the Part I study area. The Part II hydraulic analysis identified a likely route for augmentation, known herein as Route 1. It is bounded by the Drachman Street right of way (ROW) corridor and proceeds west 5,095 LF between Santa Rita Avenue and 7th Avenue. At 7th the route jogs north then west and north again for 394 LF via the Adams Street and Stone Avenue ROW corridors. At Lee Street it turns west for 1,674 LF and then north 789 LF up an alley to Lester Street. The route follows the Lester ROW westbound for 1525 LF, turns north at 15th Avenue then west at Calle Retama for 1,370 LF where it ends just east of the Union Pacific Railroad (UPR) ROW. Route 1 ends with a total route length of 10,847 LF (see **Figure 2**).

Alternative 1 follows the original route until it reaches the intersection of Stone Avenue and Adams Street. Rather than turning north this route follows Adams west an additional 473 LF where it turns north on 9th Avenue. The route follows the 9th ROW corridor for 1,182 LF to the intersection of Lester Street where it again turns west for 1,188 LF. It rejoins the original Route 1 where Lester crosses the alleyway between Oracle Road and 11th Avenue.

Alternative 2 follows the alignment of Alternative 1 until it reaches the intersection of Lee Street and 9th Avenue where it turns west along the original Route 1 for 950 LF. At 11th Avenue the route turns north and follows the ROW for 787 LF to Lester Street where it again turns west. It rejoins the original Route 1 after 249 LF at the same alleyway Alternative 1 rejoins.

Several construction scenarios were identified for the Drachman sewershed including remove and replace, tandem parallel, and adjacent parallel. Remove and replace was immediately dismissed because of the high cost of the bypass pumping that would be required for this approach. The tandem parallel method, which entails building new pipe parallel to existing pipe both of which would operate in tandem, was also dismissed because of operational difficulties. Therefore, the construction method used for the criteria evaluation was adjacent parallel which involves building new pipe parallel to existing pipe which will be abandoned once the new pipe is in situ and operational.

EVALUATION CRITERIA

Route analysis criteria have been selected based on the potential impacts of each route. The project-specific criteria are outlined in **Table 1**, categorized by the type of overall impact. Weighting Factors (WF) are applied to each of the scoring criteria, to define the relative level of impact that each criterion imparts on the viability of the alignment. The higher the weighting factor, the higher the (negative) impact on the alignment.

Weighting factors are ideally informed by project and stakeholder needs and priorities. Subjective factors can be applied to perform a draft calculation, though stakeholder feedback should confirm and/or adjust the weighting factors based on project specific needs. For example, in Table 1, utility impacts show that gravity sewer has a higher weighting factor (8) than potable water (2). These weighting factors were determined based on the difficulty of relocating an existing sanitary sewer pipe if installation of a new gravity sewer pipe results in a utility conflict.

The relative impact of potential sanitary sewer conflict is much lower than a potable water (or any pressure pipeline) conflict, when the existing water main can be raised or lowered to resolve the conflict.

Table 1. Project Specific Scoring Criteria and Associated Weighting Factors

Impact Category	Scoring Criteria		WF	Units
Construction Impacts	Available space for new SS within R/W	X <= 5'	10	LF
		5' < X < 10'	8	LF
		X >= 10'	1	LF
	Special Crossings	Local Road (60' R/W)	4	EA
		Collector Road (>60' R/W)	8	EA
		Miscellaneous	10	EA
	Traffic - parallel	Local Road (60' R/W)	4	LF
		Collector Road (>60' R/W)	8	LF
	Ex SS Service Disruptions	# of Parcels	5	EA
Utility Impacts	Parallel Utilities	Potable water	2	LF
		Gravity Sewer	8	LF
		Communications	2	LF
		Elec (UG)	4	LF
		Gas	6	LF
	Utility Crossings	Potable water	2	EA
		Gravity Sewer	8	EA
		Communications	2	EA
		Gas	6	EA
Cost Impacts	Cost Estimate	OPCC	10	$M

PROJECT-SPECIFIC SCORING CRITERIA – DEFINITIONS

Construction Impacts – Conditions related to the constructability of the pipeline

- **Available space for new Sanitary Sewer within the existing Right of Way:** Three conditions were defined for available space given the location and density of existing utilities for this project. These conditions are: <5' available width, width between 5' and 10', and width that exceeds 10'. The less width that is available, the more difficult the installation. Weighting factors were applied that reflect a higher impact for a narrower available width.
- **Special Crossings:** Three conditions were defined for special crossings given the publicly available GIS data. The routes were potentially impacted by local roads (defined as a 60' right of way width), collector roads (defined as a right of way width that exceeded 60'), and miscellaneous crossings. Miscellaneous crossings in this case were represented by an existing 16" PCCP WM and a drainage structure crossing. Coincidentally, all routes were impacted by all of the miscellaneous crossings, therefore impacts due to miscellaneous crossings were equal across all alternatives.
- **Traffic – parallel:** Conditions for parallel traffic impacts were defined by the type of

road (local or collector) where the route is located. Collector roads result in a higher impact to the need for maintenance of traffic, signage, and potential detours.

- **Existing Sanitary Sewer Disruptions:** Services to existing parcels are affected in different ways depending on where and how the new SS is placed. In the R 1 alternative, where the existing SS is being removed, all SS services from adjacent parcels are impacted by the construction of new sewer. In the parallel sewer alternatives, approximately half of all adjacent parcels are affected, since the new SS is located on one side of the ex SS which it parallels.

Utility Impacts – Conditions related to the potential for conflicts with existing utilities

- **Parallel Utilities:** Impacts due to parallel utilities affect the ability to provide adequate horizontal clearance between the new SS and existing utilities. Horizontal clearance is based on the type of utility. Existing utilities encountered in the area include potable water, gravity sewer, communications, underground electric, and gas. Potable water and gas reflect the highest weighting factors due to the horizontal separation required between SS and PW, and the critical and risky nature of gas utilities.
- **Utility Crossings:** Impacts due to perpendicular utility crossings affect the ability to locate new SS in a way that does not interfere with the existing utilities that cross the route. Gravity sewer reflects the highest weighting factor due to the inability to vertically relocate/adjust a gravity sewer pipe as opposed to the relative ease in being able to vertically relocate a pressure pipe (or communication/gas utility).

Cost Impacts – The effect of overall construction cost

- Cost impacts reflect a bottom up opinion of probable construction cost. An opinion of probable construction cost was developed for each alternative, based on unit costs for the project elements.

ROUTE SCORING MATRIX

The Route Scoring Matrix calculates the Total Impacts for each route, with a lower Impact indicating a preferable route. The basis for calculations within the Route Scoring Matrix are described below.

Each quantity of the elements listed in the Scoring Criteria is multiplied by the weighting factor for that respective criteria, to obtain an Impact Score for each criterion. To make direct comparisons among the scoring criteria (since the scale and type of quantities vary), a normalization is required, in this case a linear distribution was applied based on the minimum (non-zero) quantity. The distribution assumes that the minimum Impact Score of all routes represents a score of 1, and all other impact scores are scaled based on the minimum. The scores can then be summed within each Impact Category. Applying the Weighting Factor to each Impact Category, the route alternatives can then be compared against each other; a route with a lower Impact represents the preferable route.

Each column listed below describes the route being scored: Drach-EC-Adj is the existing Drachman corridor, Drach-Alt1C-Adj describes the route identified as the Alternative 1 corridor, and Drach-Alt2C-Adj is representative of the route identified as the Alternative 2 corridor. The abbreviation “Adj” is simply a reference to the construction method considered for each route; adjacent parallel.

Table 2 and **Figure 3** quantifies and summarizes the resulting total impact for each of the routes.

Table 2. Total Impact per Route

Impact Category	Total Impact per Route		
	Drach-EC-Adj	Drach-Alt1C-Adj	Drach-Alt2C-Adj
Construction Impacts	8.02	8.00	8.08
Utility Impacts	6.17	4.00	5.56
Cost Impacts	10.62	10.00	10.03
Total Score	**24.81**	**22.00**	**23.67**

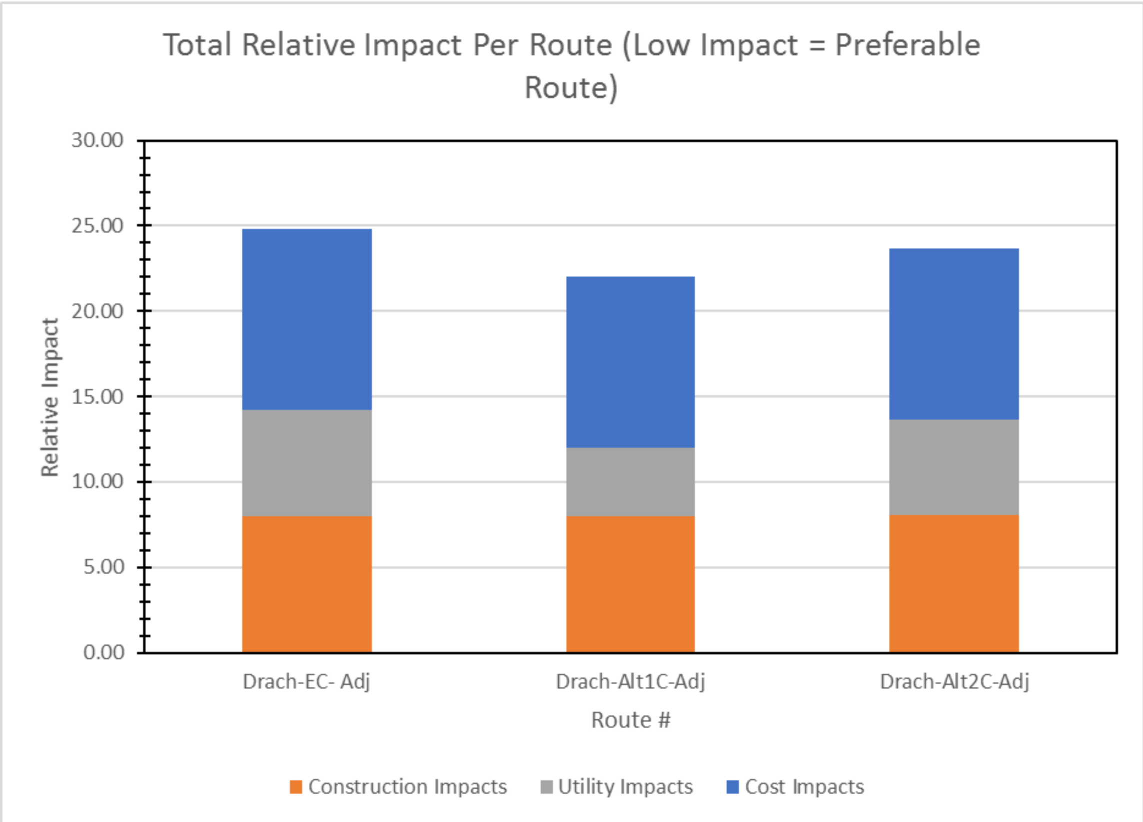

Figure 3 – Total Impact per Route

CONCLUSION

As presented above, the lowest impact route (based on the project-specific scoring criteria and associated weighting factors) is Drachman Route 1 Alternative 1. This route represents the lowest overall impact, the lowest impact in terms of utilities, and is comparable to the other (parallel sewer) alternatives in terms of construction impacts and cost impacts.

The route that requires replacement of the existing infrastructure represents the overall largest impact among all routes (i.e. least preferable alternative). This alignment is associated with a section that runs through an alley with very limited right of way and a severely strained construction corridor.

It is important to note the potential to optimize the route selection based on the interests of all project stakeholders. Optimization is possible via the adjustment of weighting factors, associated both with the impact category and the project specific scoring criteria. Involving all stakeholders in the definition of the weighting factors is critical to ensure that the priorities of all affected parties are reflected in the route selection process.

An important result of a route selection based on a weighted ranking analysis is the ability to justify the recommended route based on the scoring matrix. The reasoning behind recommending a selected route is transparent, documented, and available for justification when moving forward with future stages of design.