Memo

Stantec

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	RTC		Stantec - Reno
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Reference: Plan Line Study for the SE Connector
Alternate Alignment Analysis

TASK 2.1.D.2 Alternate Alignment Analysis

Stantec Consulting Inc. was retained by the RTC to perform a plan line study of the Southeast Connector extending from the existing intersection of South Meadows Parkway and Veterans Parkway to the intersection of Greg Street and Sparks Boulevard. The alignment will consist of an approximately 5.7 mile long, 6-lane high access control arterial roadway. This plan line study is limited to the previously established Valley Corridor (see Figure 1).

This project memorandum addresses Task 2.1.D.2 Alternate Alignment Analysis, of the contract, which was to identify viable alternatives. Stantec utilized the planning software Quantm to analyze multiple alignments and then reduce the number of potential alignments to the three (3) conceptual alignments for consideration by the RTC board. The following summarizes the analysis.

Quantm
Quantm is a planning level route optimization software program that allows integration of environmental, community, engineering and cost considerations within a single analysis to determine alignments possible within a specific corridor.

The system allows for users to input necessary constraints into the proprietary software which restricts the corridor and allows Quantm to determine a series of alignments that meet the design constraints. After Quantm calculates the alignments, additional analysis can be performed within Quantm to reduce impacts, mitigate at isolated locations or further develop the alignments chosen into a preliminary design. The task is an iterative process of refinement.

Quantm Constraints
Quantm utilizes the basic parameters described above to initially develop alignments within a specific corridor. These parameters include geometric standards and cost parameters. The following describes the inputs for these parameters.

Geometric standards

- Route Type – Two options are available; road and rail
- Geometric Type – Users can create multiple geometric scenarios for specific areas inside the Quantm program
- Carriageway – A divided or non-divided road can be utilized in Quantm, along with pavement width, shoulder width for fill and cuts, interior separation width for divided roads, and median widths for vertically divided roadways
- Grades – Design and sustained grades can be inputted along with a sustained grade maximum linear distance.
- Curves – Users can input minimum horizontal radius with corresponding super elevation and K-values for crest and sag curves. Also sight distance, eye level, and object level can be added for horizontal curvature. Quantm also adds a value for horizontal and vertical "stiffness." This stiffness values ranges from 0.1 to 1.0 with 0.1 allowing for the alignments to meander to the minimum horizontal and vertical curvature, and 1.0 restricting the alignments to more linear curvature.

A summary of values utilized for the previously described parameters are shown in table 1.

Table 1 – Geometric Standards

Parameter	***Values Utilized***
Route Type	**Road Alignment**
Geometric Type	**A single geometric scenario was created for the entire corridor**
Carriageway	**The alignment used a non-divided road, with a roadway width of 92 ft, and shoulder widths of 10' to simulate shared use paths**
Grades	**Design grades: -5% downhill and 5% uphill** **Sustained grades: -5% downhill and 5% uphill** **Maximum sustained grade distance: 5280 ft.**
Curves	**Minimum horizontal radius: 1190 ft with 4% superelevation** **Stiffness: 0.5 horizontal and 0.5 vertical** **K-values: 114 crest, 115 sag** **Coordination: sight distance 495 ft, eye level 3.5 ft, object level 1.5 ft.**

Cost Parameters

- Global – These are the base costs for the entire corridor and include user inputs for pavement thickness, earth movement with haul cost, dump and borrow costs, fill costs, fill slope, fill height to require benching and benching width.

- Culvert – Users can input specific pipe costs, headwall costs, pipe diameter and minimum cover for a variety of user specified culverts. The program also allows for two weighting factors depending on how the culvert is being used. The straight distance method is used for a culvert from point A to point B in a straight line. The path distance method is for a culvert that could follow a nonlinear path such as a stream bed or overpass for a curvilinear road.
- Bridge – Bridge costs and abutment slope can be added for many types of bridges.
- Tunnel – Tunnel costs and cross sectional area of tunnel can be added for multiple tunnels
- Wall – Wall costs and slope of walls can be added for multiple walls**.**
- Material – Users can input different types of soils with associated cost. Users can also classify the material as either "strip" (waste) or "ordinary" with an associated value from 0 to 100 for the percentage of usable material. The maximum slope and cost can be specified.
- Geology – This is a unique function for the planner/engineer where geologic materials are assigned parameters such as height needed for benching and benching width for cut slopes. Geologic materials are delineated by area and thickness.
- Area – This parameter allows the user to input area costs based on roadway footprint, fill slope, or cut slope with an additional margin to allow for a buffer outside these parameters.
- Linear – This parameter allows the user to add costs to linear features such as roads, utilities, etc.
- Fixed – This cost is for any specific costs that are associated with the corridor to be associated with any alignment generated within Quantm.

A summary of the values used for the cost parameters are shown in Table 2.

Table 2 – Cost Parameters

Parameter	***Values Utilized***
Global	**Pavement (Structural Section) cost: $80/cy with a thickness of 1.5 ft** **Earth movement costs: $3.0/cy/mi for haul, $15/cy for dump and $15/cy for borrow** **Fill: $15/cy fill rate with a fill slope of 6:1, benching height of 33 ft and benching width of 10 ft**
Culvert	**Sierra Pacific Overhead: Cost of $200/lf to underground existing overhead power for the roadway.**

Table 2 Continued – Cost Parameters	
Parameter	***Values Utilized***
Bridge	**$1,260.00/sy for cost of bridge with 2:1 slopes on abutments**
Tunnel	**Not applicable to the project**
Wall	**MSE Wall: $450/sy was used for walls on the alignment**
Material	**SEC Qa: Soil classification mainly within the alignment corridor in the low lying regions. Cost for excavation of $1.50/cy with a 3:1 max slope and 10% usable material.** **SEC Ta3: Soil Classification mainly within the mountain regions of the alignment corridor. Cost for excavation of $1.50/cy with a 1.5:1 max slope and 75% usable material.**
Geology	**SEC Qa: Soil classification with benching height of 30 ft and benching width of 10 ft.** **SEC Ta3: Soil classification with benching height of 30 ft and benching width of 10 ft.**
Area	**Agricultural Right of Way: Cost of $72/sy** **Developed Right of Way: Cost of $135/sy** **Un-developed Right of Way: Cost of $72/sy** **Wetlands: Cost of $31/sy or $150,000/acre**
Linear	**No linear costs were established**
Fixed	**No fixed costs were established**

Quantm Constraint Input

The cost and geometric parameters are the first step in determining the alignment alternatives in Quantm. The next step was to input any constraints necessary to restrict the corridor to allow Quantm to analyze the alignments. The constraints were added in order of importance in restricting the corridor as shown below.

Quantm Run 1

Quantm is restricted to the project corridor that was determined from the Southeast Connector Corridor Study (see figure 1). Quantm requires begin and end points to determine the path of the alignments. Elevations and coordinates were entered at the beginning point at the intersection of South Meadows Parkway and Veterans Parkway, and at the end point at the intersection of Greg Street and Sparks Boulevard.

Quantm Run 2

Roadways in the valley corridor were added to Quantm under the classifications of local, collector, and arterial roadways. Vertical constraints to maintain the alignment above existing centerline elevations were added at the 4 major roadway crossings of Alexander Lake Road, Mira Loma Drive, Pembroke Drive, and Cleanwater Way. Underground utility vertical constraints for gas, water, and

sewer were added to restrict the alignment from going below existing ground in areas of underground utilities.

Quantm Run 3
The Washoe County parcel base was added restricting the alignment to avoid any residential parcels; specifically the Heron's Landing and Rosewood Lake communities and specific commercial and industrial parcels at the intersection of Sparks Boulevard and Greg Street.

Quantm Run 4
Geotechnical, geological, and mining constraints were added and were associated with specific geological costs. Land owners were added with costs. Parks and recreation areas were entered and costs were added specifically to Rosewood Lakes Golf Course.

Quantm Run 5
Water bodies were added to limit the corridor based upon location of existing streams, ponds, and rivers. Major crossings through the corridor include the Truckee River, Steamboat Creek, Boynton Slough, and various ponds within the Rosewood Lakes Golf Course. Bridge and viaduct constraints were added to the water bodies to force the alignment above existing ground at crossings.

Quantm Run 6
The Zone 1 Critical Flood Pool was added with cross sectional elevations to force the alignments to be above the flood pool. Also added was the Steamboat Creek restoration realignment.

Quantm Run 7
Wetlands were added with associated costs for wetland area impacts; as per the Gibson and Skordal report dated 3/3/08. The wetlands were not specified as "total avoid" zones as Quantm would not be able to generate any alignments from Mira Loma to Pembroke. Wetland costs (as a surrogate to wetland area impacted) were broken out by Quantm for evaluation.

Quantm Run 8
Cultural/Archeological sites were added to Quantm; as per the Kautz Environmental Consultants report dated 9/8/08. Costs and "avoid" zones were associated with sites to restrict the alignments.

Quantm Analysis
After all geometric, costs, and user parameters for each run, as detailed above, are inserted into Quantm, the program transmits all the information to the main Quantm IT center for analysis. The Quantm IT Center compiles all the information, performs quality control checks on the inputs, performs the analysis, and the data is sent back to

the user for review and analysis on each alignment. Millions of alignments are analyzed through Quantm but only fifty (50) representative alignments are returned to the user. When the alignments are returned to the user, Quantm summarizes and arranges each alignment for each alignments cost.

Stantec utilized three (3) representative alignments from Quantm that minimized wetland and cultural/archeological impacts and mitigation, provided a spectrum of horizontal separation between alignments throughout the corridor, and mitigated preliminary flood impacts. Prior to presenting the alignments to the RTC Board, the costs, footprint, flood mitigation, residential buffering, and other physical constraints were further evaluated.

Alternate Alignment Analysis

The Quantm analysis yielded three (3) alignments that required further evaluation. Two of the alignments were singular alignments, whereas the third was a combination of three different alignments from Quantm. These alignments were called Alignment RTC 7-25-37, Alignment RTC 9-34, and Alignment RTC 10-40. Within the corridor, there were four (4) segments (listed below) along the original corridor that was considered in the evaluation of the three alignments (see Figure 2). These evaluation areas and alignments within are described below.

Segment 1 – South Meadows Parkway to the Huffaker Narrows, Figure 3

- Alignment RTC 7-25-37 – Begins at the intersection of South Meadows Parkway and Veterans Parkway running north along the west side of the corridor and travels northeasterly to the middle of the segment then continues northwesterly along the east side of the segment to the Huffaker Narrows. The vertical alignment is above existing ground without any vertical constraints.
- Alignment RTC 9-34 - Begins at the intersection of South Meadows Parkway and Veterans Parkway running north along the west side of the corridor, then travels northeasterly the first third of the segment on the west half, northwesterly the second third to the east side of the corridor, and northerly the final third of the segment on the east half of the corridor. The alignment utilizes the hill at the north-west portion of the segment to allow for a proposed dam location at the Huffaker Narrows. The vertical alignment was constrained to stay above the 100-year water surface elevation for a proposed dam at Huffaker Narrows.
- Alignment RTC 10-40 - Begins at the intersection of South Meadows Parkway and Veterans Parkway and then travels northerly for two-thirds of the segment along the west side of the corridor and then heads northeasterly to northwesterly for the final third. The alignment follows a proposed dam location at the Huffaker Narrows. The vertical alignment was constrained to stay above the 100-year water surface elevation for a proposed dam at Huffaker Narrows, and the vertical alignment was

established to allow the alignment to be part of the proposed dam embankment.

Segment 2 – Huffaker Narrows to Mira Loma Drive, Figure 4

- Alignment RTC 7-25-37 – From the Huffaker Narrows, the alignment continues to travel in a northwesterly direction along the west side of the corridor to the midpoint of the segment then heads northeasterly to the east side of the corridor at the intersection of Mira Loma. The vertical alignment is constrained to stay above the Truckee River 117-year flood elevations and to maintain one (1) dry lane in each direction.
- Alignment RTC 9-34 – From the Huffaker Narrows, the alignment travels in a northwesterly direction at the base of the mountains on the east side of the segment. The alignment follows the base of the mountains and then heads northerly at the south side of Mira Loma. The vertical alignment reduces in elevation from the top of the hill to the Truckee River 117-year flood elevations and maintains one (1) dry lane each direction above the design flood elevations.
- Alignment RTC 10-40 – From the Huffaker Narrows, the alignment travels northeasterly to the mountains on the east side of the segment. The alignment then follows the mountain terrain with the alignment on the side of the mountain, and then heads northerly just south of Mira Loma. The vertical alignment is constrained at the Huffaker Narrows to allow the alignment to be part of the proposed dam embankment. The vertical alignment is then constrained at the hillside at an elevation which approximately balances cut and fill quantities.

Segment 3 – Mira Loma Drive to Pembroke Drive, Figure 5

- Alignment RTC 7-25-37 – From Mira Loma the alignment continues in a northeasterly direction and runs parallel to the Steamboat Creek along the east side of the segment. The vertical alignment is constrained by the elevations of the Truckee River 117-yeard flood elevations with the vertical alignment maintaining one dry lane of traffic in each direction. The vertical alignment is also constrained by the Boynton Slough.
- Alignment RTC 9-34 – From Mira Loma the alignment continues to the northeast and parallels Steamboat Creek for the first third of the segment. The alignment then travels northerly to the northwest side of the golf course with the crossing of Boynton Slough near the existing clubhouse. The vertical alignment is constrained to allow one dry lane in each direction above the Truckee River 117-year flood elevations.
- Alignment RTC 10-40 – From Mira Loma the alignment travels through the east third of the golf course in a northeasterly direction and then continues to the east side of the golf course to Pembroke Drive. The vertical alignment maintains one dry lane in each direction above the Truckee River 117-year flood elevations.

Segment 4 – Pembroke Drive to Greg Street, Figure 6

- Alignment RTC 7-25-37 – The alignment travels in a northerly direction away from Pembroke and then continues northeast along the west half of the corridor to Cleanwater Way where the alignment curves to a northwesterly direction to the project's terminus at the intersection of Sparks Boulevard and Greg Street. The vertical alignment is constrained to maintain one dry lane each direction above the Truckee River 117-year flood elevations. The alignment also rises over Cleanwater Way to allow for truck traffic under the alignment and rises over the Truckee River to allow proper clearance over the Truckee River for flood conditions.
- Alignment RTC 9-34 – The alignment travels in a northeasterly direction along the west side of the segment and continues across the segment to the east side and then travels to the northwest to the project's terminus at the intersection of Sparks Boulevard and Greg Street. The vertical alignment is constrained to maintain one dry lane each direction above the Truckee River 117-year flood elevations. The alignment also rises over Cleanwater Way to allow for truck traffic under the alignment and rises over the Truckee River to allow proper clearance over the Truckee River for flood conditions.
- Alignment RTC 10-40 – The alignment continues to the northeast through the middle of the segment toward the east side of the segment and then continues north of Cleanwater Way to the northwest to the project's terminus at Sparks Boulevard and Greg Street. The vertical alignment is constrained to maintain one dry lane in each direction above the Truckee River 117-year flood elevations. The alignment also rises over Cleanwater Way to allow for truck traffic under the alignment and rises over the Truckee River to allow proper clearance over the Truckee River for flood conditions.

The analysis above describes the planning level design for the alignments through the Valley Corridor. These alignments represent the spectrum of alignments on the east, middle and west sides of the corridor. The alignments have incorporated the constraints consisting of: geotechnical, cultural/archeological, flood considerations, wetlands, existing utilities and other general physical or imposed constraints. Further action was undertaken to continue the analysis of the alignments from a planning level stage with Quantm to a planning level based upon more detailed engineering analysis.

AutoCAD Analysis

Since Quantm is a planning level design program, more analysis was necessary on each alignment and performed with engineering models in AutoCAD to analyze the alignments in a more detailed manner. These parameters are described below.

Intersections

Quantm does not have the capability of inputting elements of intersection design into the alignments. The intersections are key elements in the alignment analysis since none of the intersections had the same geometry. Each intersection required analysis for turn lanes, deceleration lanes, acceleration lanes, and through lanes needed to determine a general footprint. Refer to the design memorandum for Task 2.1.C entitled Traffic Analysis Report for a discussion of the traffic analysis and intersection layout figures.

Slopes

Quantm can have multiple slopes, as described in cost parameters, associated with each alignment through specific areas. There is no capability though, to associate additional costs for barrier, guardrail, or slope stability when changing dynamically between slopes. With Quantm the right-of-way is associated with the toe of slope. AutoCAD can determine the right-of-way area based upon the toe of the slope or can determine right-of-way from specific offset distances.

Vertical and Horizontal Alignments

Quantm utilizes vertical and horizontal alignments to minimize cut and fill quantities and horizontal footprint. Quantm is limited in its analysis because the horizontal and vertical alignments are typically curvilinear rather than tangential to minimize impact. AutoCAD needed to be utilized to import the alignments both horizontally and vertically, and manipulate these for more realistic values.

Earthwork

Quantm can accurately calculate earthwork quantities for the entire alignment and associated costs. As described above, Quantm does not include intersection design which limits the ability of Quantm to perform accurate earthwork at these locations. With the additional analysis in AutoCAD, a more accurate earthwork quantity can be produced.

Through the use of AutoCAD, the three alignments were refined, and presented to RTC. More detailed analysis and refinement of the three alignments was necessary to develop a single recommended alignment. An evaluation matrix, as shown in Table 3, was developed with the Quantm constraints data in combination with the AutoCAD analysis data to reduce the three alignments to a singular alignment for recommendation as shown below.

Table 3 -Evaluation Matrix			
Conformity with Planning	***RTC 7-25-37***	***RTC 9-34***	***RTC 10-40***
Regional Park Plan	Yes	Yes	Yes
Bella Vista	Yes	Yes	Yes
Butler Ranch	No	Yes	Yes
Rosewood Lakes Golf Course			
Impact to Rosewood Lakes	Least	Most	Middle
Cultural/Archeological			
Avoids Known Significant Archeological Sites	Yes	Yes	Yes
Wetlands			
Area of Encroachment	Least	Most	Middle
Mitigation	TBD	TBD	TBD
Lakes and Ponds			
Affected Area	Middle	Least	Most
Right of Way			
Amount of Right-of-Way Required (Undeveloped)	34 acres +/-	37 acres +/-	90 acres +/-
Amount of Right-of-Way Required (Developed)	25 acres +/-	20 acres +/-	23 acres +/-
Amount of Right-of-Way Required (Agriculture)	52 acres +/-	49 acres +/-	36 acres +/-
Residential Buffering			
Closest Distance to Heron's Landing Residences	270 ft +/-	370 ft +/-	235 ft +/-
Closest Distance to Hidden Valley Residences	1130 ft +/-	625 ft +/-	790 ft +/-
Closest Distance to Rosewood Lakes Residences	115 ft +/-	450 ft +/-	280 ft +/-
Structures			
Truckee River Bridge Crossing	500 ft +/-	500 ft +/-	500 ft +/-
Total Length of Conveyance Structures	12,500 ft +/-	12,500 ft +/-	12,500 ft +/-
Streams			
Steamboat Creek Realignment/Restoration	Middle	Most	Least
Zone 1 Critical Flood Pool Storage			
Volume of Water Displaced	Most	Middle	Least
Avoid Effects to Hidden Valley TRAction Project	Yes	Yes	Yes

Extras to Comply with Truckee River Flood Project	***RTC 7-25-37***	***RTC 9-34***	***RTC 10-40***
Truckee River Bridge – Additional Length Due to Benching	**300 ft +/-**	**300 ft +/-**	**300 ft +/-**
Truckee River Bridge - Additional Height	**2 ft**	**2 ft**	**2 ft**

Opinion of Probable Construction Cost	
RTC 7-25-37	**$157-170 million***
RTC 9-34	**$158-172 million***
RTC 10-40	**$190-207 million***

* In providing opinions of probable cost, it is recognized that neither the Client nor Stantec has control over the costs of labor, equipment or materials, or over the Contractor's methods of determining prices or bidding. The opinion of probable costs is based on Stantec's reasonable professional judgment and experience and does not constitute a warranty, express or implied, that the Contractor's' bids or the negotiated price of the Work will not vary from the Client's budget or from any opinion of probable cost prepared by Stantec.
** Note that an opinion of probable construction and right-of-way cost of $144 to $202 million was provided early in the plan line study. Its accuracy was consistent with the level of effort and design details investigated at that time. Additional information obtained during the remainder of the plan line study revised this opinion of probable construction and right-of-way cost to $157 to $207 million.

Final Alternate Alignment

Stantec, with the input of RTC, developed the final alignment from the three alternate alignments described previously. To assist in the determination of the final alignment, Stantec and RTC performed an on site walk-through to observe constraints in person rather than in a computer setting. This walk-through in association with continual analysis helped determine the final alignment (see figures 7 to 12). The pros and cons leading to the selection of the recommended alignment are discussed below.

Segment 1 – South Meadows Parkway to Huffaker Narrows

A western alignment would be more preferable then an eastern alignment since the crossing at the narrows would need to be on the west side in order to avoid the BLM land on the east side of the segment, and cultural resource constraints. This restricts the alignments to RTC 9-34 and RTC 10-40 and eliminates the need for RTC 7-25-37. Further discussion between the two alignments concluded with eliminating RTC 10-40 since RTC 9-34 had a similar alignment and had less horizontal curvature. Also RTC 9-34 could allow for a crossing of a proposed dam at Huffaker Narrows just as RTC 10-40's alignment already achieves.

Segment 2 – Huffaker Narrows to Mira Loma Drive
From Huffaker Narrows, RTC 9-34 and RTC 10-40 alignments travel along the east edge of the corridor whereas RTC 7-25-37 continues through the middle of Butler Ranch. RTC 7-25-37 was not considered since the alignment creates additional length and is detrimental to the Butler Ranch area by creating a barrier in the middle of the existing ranch. RTC 9-34 and RTC 10-40 were then analyzed and a hybrid of the two alignments was developed to utilize the mountain on the east side of the corridor for a possible borrow source while allowing the Steamboat Creek to be mitigated to the west of the alignment. Additionally, there were significant cultural/archeological impacts within the segment that the recommended alignment avoided.

Segment 3 – Mira Loma Drive to Pembroke Drive
Wetland areas were a critical concern through the golf course segment. The alignments of RTC 7-25-37 and RTC 10-40 were both eastern alignments and impacted more wetland areas than RTC 9-34. Additionally, RTC 7-25-37 and RTC 10-40 would need to realign the Boynton Slough to allow the crossing of Pembroke Drive at a reasonable elevation. The separation to adjacent homes is also maximized in the RTC 9-34 alignment for residential buffering.

Segment 4 – Pembroke Drive to Greg Street
The main concerns on the segment were Steamboat Creek and UNR Farms. Each alignment maintains a reasonable distance from Steamboat Creek to allow for meandering flow. UNR Farms has a large fill area in the northern portion of the property that needed to remain intact for the continuing operations of the Farms. Only RTC 10-40 allows for this condition. North of the fill area the three alignments converge to the terminus at Greg Street.

The final alignment, RTC 34-40, was created as a hybrid from the descriptions above. Table 4 shows the results of the cost analysis performed on the RTC 34-40 alignment as well as costs for the 3 alignment alternatives. Note that these updated costs take into account engineering services during design and construction that were developed during the process of refining the hybrid alignment with more detailed analysis. These costs represent a single constructed roadway, beginning to end, with no allowance for additional costs associated with multiple construction phases.

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Table 4 - Updated Opinion of Probable Construction Cost	
RTC 7-25-37	$191-208 million*
RTC 9-34	$193-210 million*
RTC 10-40	$232-252 million*
RTC 34-40	$203-221 million*

* In providing opinions of probable cost, it is recognized that neither the Client nor Stantec has control over the costs of labor, equipment or materials, or over Contractor's methods of determining prices or bidding. The opinion of probable costs is based on Stantec's reasonable professional judgment and experience and does not constitute a warranty, express or implied, that the Contractor's bids or the negotiated price of the Work will not vary from the Client's budget or from any opinion of probable cost prepared by Stantec.

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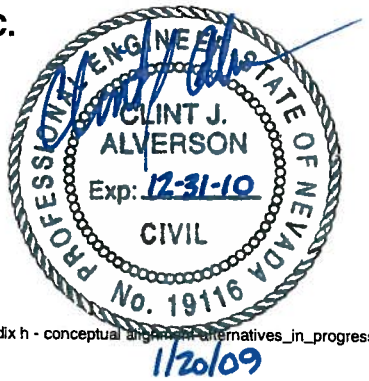

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