Science and Resource Management
Campus Comprehensive Plan

Section 2 - Transportation Flow Analysis

December 2008

A Partnership Project of
Grand Canyon National Park
Ecological Monitoring & Assessment Program, Northern Arizona University
College of Engineering, Forestry, and Natural Sciences, Northern Arizona University

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1. Preliminary Design Analysis

The goal of the following conceptual transportation flow plans was to assist in fostering a campus and community environment using the McKee building as the focal point. These plans were first summarized in the July 15, 2008 report, Grand Canyon National Park – Albright Campus Comprehensive Plan. It was noted that the garage bay/loading dock locations throughout the complex were a decisively limiting factor in the preliminary transportation flow plan design and have further been influenced by the subsequent review of comments and criticisms.

Figure 1, illustrates the site layout prior to design work. The two, existing entrances to the complex are designated as “Eastern Entrance” and “Western Entrance” and will be referred to as such herein. The site boundary was delineated on the image used, Figure 1. Three different preliminary design proposals were drafted and presented to Grand Canyon National Park in the July 15, 2008 report and revised, in the September 2, 2008 report, Grand Canyon National Park – Science and Resource Management Campus Comprehensive Plan. These plans aided the design process by opening a discussion to determine all GCNP current and potential future uses of the site. These two reports and corresponding comments and criticisms were used to develop the final proposed, transportation plan. The three preliminary plans used during the design process are briefly summarized herein.
1.1 Conceptual Transportation Flow Plan A
The focus of Conceptual Transportation Flow Plan A, Figure 2, was to route heavy-vehicles associated primarily with Xanterra, current occupant of 12 Albright and 10 Albright, traffic away from the McKee Building (Albright 2D). Trucks and deliveries for Xanterra would use the Western Entrance, and from there, reach either warehouse 10 and 12 Albright. Additional closures of roads as indicated would help create a central campus around the McKee Building. The area between the McKee and the Dutton (Albright 2E) buildings would be available as open space with the parking area displaced. The area around the North and Eastern sides of the McKee Building was reserved for an enlarged footprint and extra open space around the building.

This plan was determined not feasible due to a number of concerns raised. Primarily, safety reasons in the area required for docking at the Powell Building minimizes the open space. Also, a docked tractor would block access to a now, dead-ended, driveway. In addition, secondary parking for 12 Albright was located at the south end of the Powell Building. The car turnaround zone minimizes the real estate available for parking at that area. In conclusion, it was the recommendation of the September 12, 2008 report that dropped Conceptual Transportation Flow Plan A from consideration.
Figure 2: Conceptual Transportation Plan A
1.2 Conceptual Transportation Flow Plan B

Conceptual Transportation Flow Plan B, Figure 3, focuses on minimizing movement of heavy-vehicles through the complex and maximizing available open space. This plan would create a larger, central campus around the McKee Building as in Conceptual Transportation Flow Plan A. Xanterra traffic would be limited to the Western entrance. The refueling station and storage unit was relocated south moving heavy-vehicle traffic with it. Only the north side McKee Building garage bays were accessible. Daily traffic for the Museum, Powell, and McKee would use the Eastern entrance.

Previously identified issues caused by Plan A are applicable to Plan B. The loading bay of Powell building was inaccessible to large vehicles and a truck using the Powell Building Dock would block traffic. Xanterra parking would encounter the same issue of Plan A. Trucks attempting to reach the loading dock on the east side of 12 Albright would need to use area occupied by the turn around. Also, the trucks would need to reverse a significant distance. The potential for queuing at the refueling station could create blockages on the access road. Based on these issues, it was the recommendation of the September 12, 2008 report that dropped Conceptual Transportation Flow Plan B from consideration.

Figure 3: Conceptual Transportation Plan B
1.3 Conceptual Transportation Flow Plan C, Revision 1

Conceptual Transportation Flow Plan C, Revision 1, Figure 4, creates open space in proximity to the Dutton Building. The series of streets through the center of the complex would remain unchanged. The northern road would become a one way road pending potential building expansion. Plan C also does not require the closing of any current roadways leaving it the most open Plan with regard to traffic. Critical access to complex loading docks remains unhindered and safe.

Review was conducted of the Grand Canyon National Park correspondence and considered with additional input from current tenants Xanterra and Grand Canyon Association regarding the Albright Campus Comprehensive Plan preliminary reports. Plan C was revised and selected by Grand Canyon National Park for development.

Figure 4: Conceptual Transportation Plan C, 1st Revision
2. Parking

2.1 Demand

ITE, Table 14-2, p. 509, recommends a ratio of 3.30 parking spaces per 1,000 sq ft or 1.02 parking spaces per employee. The new McKee Building will house 49 employees with a 60 person capacity conference room. As measured using the provided aerial imagery, there is approximately 14,500 sq ft gross floor area of the existing McKee Building. The proposed, new McKee Building will have approximately 7,000 sq ft leasable floor area. This was summarized in Table 1. The number of recommended parking spaces needed varied between 24 and 62 parking spaces.

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Ratio</th>
<th>Parking Spaces Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing McKee Building</td>
<td>14,500 sq ft</td>
<td>3.30 parking spaces/1,000 sq ft</td>
<td>48.0</td>
</tr>
<tr>
<td>Proposed McKee Building</td>
<td>7,000 sq ft</td>
<td>3.30 parking spaces/1,000 sq ft</td>
<td>24.0</td>
</tr>
<tr>
<td>Proposed McKee Building: Employees</td>
<td>49 Employees</td>
<td>1.02 parking spaces/Employee</td>
<td>50.0</td>
</tr>
<tr>
<td>Proposed McKee Building: Conference Room</td>
<td>60 Persons</td>
<td>1.02 parking spaces/Person</td>
<td>62.0</td>
</tr>
</tbody>
</table>
2.2 Existing and Recommendations

The number of existing designated parking spaces was determined using the provided, undated aerial photograph, along with information obtained through a site visit. The site at the time of “photographing” contained 86 parking spaces. This number contains 9 parking spaces currently located at 12 Albright, at time of writing, shown under construction at time of “photographing,” in Figure 1. Of the 86 designated parking spaces, 33 border 2D Albright, the McKee Building. Four of the 86 parking spaces are classified as Accessible Spaces with access aisle sized for passenger cars. None of which designated are located in the parking spaces bordering McKee Building. Table 2 illustrates the recommended spaces and any associated designations.

Table 2: Parking Allocation Designations

<table>
<thead>
<tr>
<th>Designations</th>
<th>Parking Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Recommended, Fewest to Most</strong></td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>62</td>
</tr>
<tr>
<td>Accessible Spaces Required&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Low Emitting &amp;</td>
<td>2</td>
</tr>
<tr>
<td>Fuel Efficient Vehicles&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4</td>
</tr>
</tbody>
</table>

<sup>a</sup> SS Credit 4.4: Alternative Transportation: Parking Capacity, Would Limit parking spaces available to 33.

<sup>b</sup> Required Minimum Number of Accessible Spaces, USDOJ, p. 497

<sup>c</sup> SS Credit 4.3: Alternative Transportation: Low Emitting & Fuel Efficient Vehicles, Number of Designated Spaces needed.

While the accessible spaces may be provided in a different location while providing equivalent or greater accessibility, it was the recommendation of this report to place those spaces in the area available surrounding the McKee Building in closest proximity to the entrance. The parking spaces were designated according to proximity to both the entrance currently facilitating as main entrance and the area for the proposed, new McKee Building entrance. (USDOJ, p. 497)

2.3 Typical Parking Space

2.3.1 Design Vehicle

Design vehicles have representative characteristics for vehicles found within its particular class. There are four general classes of design vehicles. These classes consist of passenger cars, busses, trucks, and recreational vehicles. The AASHTO 2004 Passenger Vehicle Design Vehicle, P, was selected for
determining parking space stall width and length. Figure 5 illustrates Design Vehicle P whose plan view footprint dimensions are 19 ft by 7 ft. (AASHTO 2004, pg. 15-21)

![Figure 5: Passenger Car Design Vehicle, P](image)

**Table 3: Passenger Car Design Vehicle Dimensions**

<table>
<thead>
<tr>
<th>Overall Characteristic</th>
<th>Dimensions, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height $^a$</td>
<td>4.25</td>
</tr>
<tr>
<td>Width $^b$</td>
<td>7.00</td>
</tr>
<tr>
<td>Length $^c$</td>
<td>19.00</td>
</tr>
<tr>
<td>Wheelbase $^d$</td>
<td>11.00</td>
</tr>
</tbody>
</table>

$^a$ Measured from undercarriage to roof crown.  
$^b$ Measured bumper edge to bumper edge.  
$^c$ Measured front bumper to rear bumper.  
$^d$ Measured center of front axle to center of rear axle.

### 2.3.2 Accessible Spaces
Accessible Spaces are defined based on minimum dimensions set by the Americans with Disabilities Act, Standards for Accessible Design. Figure 6 was provided to illustrate the minimum dimensions required for parking space width and passenger car access aisles. This image was duplicated from USDOJ, Fig. 9, p. 517. The minimum dimension for stall widths was designated at 96 in with a 60 in aisle adjacent to the left side or right side of the stall. This aisle may be shared by two accessible parking spaces (USDOJ, p. 516).
USDOJ, p. 497, states that one in every eight accessible spaces, but not less than one, shall be served by an access aisle 96 in wide, minimum. This stall shall be designated as “van accessible”. As the number of required accessible spaces for the McKee building ranges from one to three. There will be at least one parking space designated as “van accessible” at the McKee Building.

2.3.3 Parking Stall Design
Minimum parking space design was dependent on the overall width dimension of the design vehicle. Typically this number was enlarged by adding 22 to 26 in. This number was determined by average design door opening clearance required (Weant and Levinson, p. 157). The design vehicle width of 7 ft (84 in) plus 26 in door clearance results in a parking stall minimum width of 9.2 ft (110 in). The observed width of parking stalls around the Science and Resource Management Campus aerial image range from 9.5 ft to 11.5 ft. The team recommends the selection of using 9.5 ft wide parking stalls as they meet and exceed both minimum calculated parking stall width and the minimum required width for accessible parking. In addition, this width allows the conversion of one parking space to a “van accessible” aisle for two adjacent spaces as it meets the minimum required aisle width as well. This allows for future changes in accessible space demand.

Weant and Levinson, p. 158 recommend using the design vehicles length plus a minimum of 6 in accounting for bumper clearance. This results in a minimum parking stall length of 19.5 ft. Observed lengths of striping for parking stalls at the Science and Resource Management Campus shown in the aerial image range from 20 to 21 ft. Typically stall striping on the pavement is cut short of the actual
design length of the parking stall. This is done in order to encourage drives to pull as far in to the stall as possible, increasing available aisle/driveway width and safety (Weant and Levinson, p. 158). Twenty feet was selected to closely match prior parking space width while meeting the minimum stall length.

To maximize available parking, all parking spaces will be placed 90° to the edge of pavement. An angle of 90° allows for two-way traveling of the travel aisle and better visual recognition of parking opportunities (Weant and Levinson, p. 165). Drivers are able to better see vehicles maneuvering from stalls than from angled parking spaces. The final parking stall design was summarized in Table 4.

### Table 4: Parking Stall Dimensions

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>9.5 ft</td>
</tr>
<tr>
<td>Design Length</td>
<td>20.0 ft</td>
</tr>
<tr>
<td>Angle, θ&lt;sup&gt;a&lt;/sup&gt;</td>
<td>90°</td>
</tr>
</tbody>
</table>

<sup>a</sup> Angle measured from wall or other obstruction to lengthwise edge of stall.

#### 2.4 Aisle Design

A recommended aisle width, the distance between rows of parking spaces, was calculated to be 34 ft. This number was determined using the AASHTO 2004 Passenger Car Design Vehicle characteristic dimensions and turning movement data. Combined with the Ricker Formula, an aisle width was calculated as shown in Appendix A. This width allows the design vehicle to “pull forward” into a selected parking stall. Weant and Levinson, p. 160, notes that typical aisle width equations “for 90-degree parking usually exceed the minimum aisle width actually required by the design vehicle operated with average driver ability.” Also turning radius values used from AASHTO 2004 Passenger Car Design Vehicle are determined at 10 mph for a fixed turn at a given steering angle (AASHTO 2004, pg. 18-20). This also contributed to an overestimation of the aisle width.

The calculated aisle width was nearly matched where possible. Existing geometric conditions sometimes restrict the nominal width in certain areas of the Science and Resource Management Campus. It shall be noted that the design vehicle represents the 85<sup>th</sup> percentile vehicle. The design vehicle’s dimensions are such that 85% of vehicles typically have characteristics smaller than that of the chosen design vehicle. Given all of the influencing factors of the aisle width and existing conditions at the site, an aisle width within approximately 10% of the calculated value was found adequate.
2.5 Final Layout

The final layout of the Science and Resource Management Campus focusing on the McKee Building was shown in Figure 7 and with the aerial underlay in Figure 8. Figure 7 shows the relationship between McKee Building and the Campus.

![Figure 7: Final Site Layout](image)
Figure 8: Final Site Layout with Aerial Underlay

The McKee Building was shown in Figure 9. The designated parking areas are comprised of the proportion of required accessible spaces and available geometry for their associated building. The specifics would be determined through an additional study focusing on each individual building. The McKee Building has 54 parking spaces. These spaces provided hinge on leaving the end-bays fully accessible while keeping the McKee Building docks/bays, which serve as current office space, closed. These bays could be reopened for service by the Park Service with the removal of the adjacent parking space. The 4 accessible spaces, designated by the square representing the International Symbol of Accessibility Parking, exceed the required 3 spaces based on building and auditorium capacity.
One “van accessible” space was required. The positioning of its associated aisle allows the adjacent space to also be labeled as “van accessible.” This designation does not preclude non-van accessible vehicles from parking there. The positioning of the second aisle for the third required stall allows its adjacent space to be labeled as accessible parking if deemed necessary. It should be noted that this space may also be used to meet the needs of another building within the complex. The four “X” represent the spaces needed to meet the LEED Certification Point for SS Credit 4.3: Alternative Transportation: Low Emitting & Fuel Efficient Vehicles. The number was calculated from the minimum available parking for the McKee Building alone if the Science and Resource Management Campus would place this into effect campus wide. Custom, nonstandard signs will require manufacturing as the Manual on Uniform Traffic Control Devices does not contain a standard sign for Low Emitting & Fuel Efficient Vehicle Parking.

An additional LEED Certification Point may be obtained by limiting parking based on preconstruction/renovation parking capacity. The number of spaces was determined using the aerial image to be 33. This would qualify for SS Credit 4.4: Alternative Transportation: Parking Capacity. Spaces from Figure 9 would be removed to lower the capacity from the shown 54 spaces to 33 spaces. In order to meet the “Most” capacity, shown in
Table 2, parking would need to be allocated at nearby complex buildings (referred to as secondary buildings, where McKee Building is the primary/focus). These ‘floating’ spaces would displace parking from the secondary building(s) to tertiary building(s) or a standalone surface lot. The quantity of parking spaces displaced from other Science and Resource Management Campus buildings would require additional study based on more in-depth, individual building needs not covered by this report.
3. Signage and Striping

A number of standard signs exist currently at the Science and Resource Management Campus. These signs include stop signs, do not enter signs, speed limit sign, accessible parking signs, and no parking signs. These signs are shown as experts from the Manual on Uniform Traffic Control Devices in Table 5. As part of the Transportation Plan, these signs will remain in place and shall be supplemented with signs from Table 6. However, it is recommended that the “One Way” signs, MUTCD R6-2R, be removed from the “Do Not Enter” signs’, MUTCD R5-1, sign post. The “One Way” signs can lead to driver confusion. There are no additional travel lane limitations at that location presented in this Transportation Plan.

The current speed limit in the Science and Resource Management Campus is 15 miles per hour. This was posted at only the Eastern Entrance and shall be added to the Western Entrance. The sign style used was R2-1 with the numerals “1” and “5” in place of those shown in Table 5. A combination of W11-2 and W16-7p shown in Table 6 shall be placed on the right-hand-side of approaching lanes to a designated crosswalk to call driver attention. The sign layout of the campus was illustrated in Figure 10.

Table 5: Existing Signage

<table>
<thead>
<tr>
<th>R1-1</th>
<th>R2-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="STOP sign" /></td>
<td><img src="image" alt="SPEED LIMIT 50 sign" /></td>
</tr>
<tr>
<td><img src="image" alt="DO NOT ENTER sign" /></td>
<td><img src="image" alt="ONE WAY sign" /></td>
</tr>
<tr>
<td>R5-1</td>
<td>R6-2R</td>
</tr>
</tbody>
</table>
Table 6: Additional Signage

- **R7-1**
  - (with Double Arrow)
- **D9-6**

- **R5-1a**
  - **WRONG WAY**
- **R6-1**
  - **ONE WAY**

- **R7-8b**
  - **VAN ACCESSIBLE**
- **W11-2**

- **W16-7p**
The Manual on Uniform Traffic Control Devices specifies standards and guidance for striping and pavement markings. Applicable markings that should be applied to the sites cleaned and/or resurfaced parking and roadway system are detailed in Table 7. Pigments used should match existing paint pigments used within Grand Canyon National Park to meet driver expectations. These dimensions were used to draw scale sized parking spaces and accessible aisles of Figure 10. Also, the striping details were used to determine and check available driveway aisle widths.
### Table 7: Striping Details

<table>
<thead>
<tr>
<th>Type</th>
<th>Color</th>
<th>Dimensions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripe, Longitudinal Line</td>
<td>White</td>
<td>4 in, Solid</td>
<td>Parking Space Line Delineation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MUTCD, Section 3A.05, p. 3A-2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MUTCD, Section 3B.18, p. 3B-28)</td>
</tr>
<tr>
<td>Stripe, Longitudinal Line</td>
<td>Blue</td>
<td>4 in, Solid</td>
<td>Accessible Parking Space Line Delineation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MUTCD, Section 3A.05, p. 3A-2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MUTCD, Section 3B.18, p. 3B-28)</td>
</tr>
<tr>
<td>Stripe, Stop Bar</td>
<td>White</td>
<td>24 in, Solid</td>
<td>Stop Bar. Indicates point behind which vehicles are required to stop in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compliance with Stop Sign, R1-1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MUTCD, Section 3B.16, p. 3B-25)</td>
</tr>
<tr>
<td>Stripe, Crosswalk Marking</td>
<td>White</td>
<td>24 in, Solid</td>
<td>Crosswalk Stripes. Shall be separated by a gap not less than 6 ft wide.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MUTCD, Section 3B.17, p. 3B-27)</td>
</tr>
<tr>
<td>Symbol, International</td>
<td>White</td>
<td>Border: 28 in</td>
<td>(MUTCD, Section 3B.19, p. 3B-28)</td>
</tr>
<tr>
<td>Symbol of Accessibility</td>
<td>Blue</td>
<td>Minimum by 24 in</td>
<td></td>
</tr>
<tr>
<td>Parking Space Marking</td>
<td></td>
<td>Minimum,</td>
<td>(MUTCD, Figure 3B-19, p. 3B-31)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Legend: 3 in</td>
<td>Minimum Stroke width</td>
</tr>
</tbody>
</table>
4. Appendix A: Parking Aisle Width Calculation

Ricker Equation for Aisle Width:

\[ AW = R' + c + \sin \theta \sqrt{R^2 - (r + t_r + O_s + i - c)^2} - \cos \theta (r + t_r + O_s + S) \]

(Weant and Levinson, Fig. 8.3, p.160)

AW: Aisle Width, ft

R': Minimum Turning Radius, Outside point, rear bumper, ft

R: Minimum Turning Radius, Outside point, front bumper, ft

r: Minimum Turning Radius, Inside rear wheel, ft

c: Clearance between stripe and outer edge of parked vehicle, ft

\( \theta \): Angle measured from wall or other obstruction to lengthwise edge of stall, ° (degrees)

t_r: Width from center of rear tires, ft

O_s: Body side overhand from center of rear tire, ft

i: Total design clearance measured from parked vehicle to adjacent parked vehicle, ft

Design Values Used:

\begin{align*}
R' & : 21.0 \text{ ft} \\
R & : 25.5 \text{ ft} & \text{(AASHTO 2004, p. 21)} \\
r & : 14.6 \text{ ft} & \text{(AASHTO 2004, p. 21)} \\
\theta & : 90^\circ & \text{Table 4: Parking Stall Dimensions} \\
t_r & : 5.3 \text{ ft} & \text{(AASHTO 2004, p. 21)} \\
O_s & : 0.5 \text{ ft} & \text{(AASHTO 2004, p. 21)}
\end{align*}
**Side Clearance:**

\[ c = \frac{1}{2} (WS - W_{dv}) \]

WS: Stall Width, ft

\[ W_{dv}: \text{Design Vehicle Width} \]

\[ c = \frac{1}{2} (9.5 \text{ ft} - 7 \text{ ft}) \]

\[ c = \frac{1}{2} \cdot 2.5 \text{ ft} \]

\[ c = 1.25 \text{ ft} \]
**Design Clearance:**

\[ i = 2 \cdot c \]

\[ i = 2 \cdot 1.25 \text{ ft} \]

\[ i = 2.5 \text{ ft} \]

**Aisle Width Calculation:**

\[ AW = R^2 + c + \sin \theta \sqrt{R^2 - (r + t_r + O_s + i - c)^2} - \cos \theta (r + t_r + O_s + S) \]

\[ AW = 21.0 \text{ ft} + 1.25 \text{ ft} + \sin 90^\circ \sqrt{(25.5 \text{ ft})^2 - (14.4 \text{ ft} + 5.3 \text{ ft} + 0.5 \text{ ft} + 2.5 \text{ ft} - 1.25 \text{ ft})^2} - 0 \]

\[ AW = 21.0 \text{ ft} + 1.25 \text{ ft} + 1 \cdot \sqrt{135.8676 \text{ ft}^2} \]

\[ AW = 21.0 \text{ ft} + 1.25 \text{ ft} + 11.6562258 \text{ ft} \]

\[ AW = 33.9062258 \text{ ft} \]

\[ AW = 34 \text{ ft} \]
5. References


