PROJECT AUTHORIZATION NO. HWY-2004-16

under

MASTER AGREEMENT FOR RESEARCH AND TRAINING SERVICES BETWEEN THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION AND NORTH CAROLINA STATE UNIVERSITY ON BEHALF OF THE INSTITUTE FOR TRANSPORTATION RESEARCH AND EDUCATION (Contract No. 98-1783)

Project Title: I-40 Reversal Operational Traffic Analysis

Formal Statement of Work: See attached proposal

Period of Performance: July 1, 2003 – June 30, 2005

Budget Authorization: FY 2003/2004 - $79,457
FY 2004/2005 - $72,443

Property to be Furnished by the Department: None

Key Personnel: PI: Billy M. Williams; Co-PI – Stephen S. Meinhold (not a signatory – UNC-W); Senior Project Advisor: Nagui M. Rouphail; Project Advisor: Joseph E. Hummer

Project Monitor: Shannon Lasater

Additional Terms and Conditions: Research Project Guidelines as posted on ITRE's website at *http://itre.ncsu.edu/research/ongoingguidelines.htm.*

IN WITNESS WHEREOF, the parties hereto have executed this Project Authorization as of

April 24, 2003.

NORTH CAROLINA STATE UNIVERSITY

BY:_____
Principal Investigator

BY:_____
N. C. State University

BY:_____
Director of ITRE

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

BY:_____

FY 2004 NCDOT RESEARCH PROPOSAL

Subcommittee: **Operations**
Project Title: **I-40 Reversal Operational Traffic Analysis**

Submittal Date: **April 24, 2003**

Project Budget: **FY2003/2004 - $79,457**
FY2004/2005 - $72,443

Organization: **North Carolina State University**
College of Engineering and
Institute for Trans. Research and Education

Researchers: Billy M. Williams, Ph.D., P.E., Principal Investigator
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Associate Professor, UNC-W, Department of Political Science

Nagui M. Rouphail, Ph.D., Senior Project Advisor
Director, Institute for Transportation Research and Education

Joseph E. Hummer, Ph.D., P.E., Project Advisor
Associate Professor, Department of Civil Engineering

Project Summary:

Following the unprecedented multi-state coastal evacuation for Hurricane Floyd in 1999, the NCDOT developed a lane reversal plan for I-40 to facilitate the safe and efficient evacuation of residents and tourists in southeastern North Carolina. The plan, approved in 2000, was developed and will be administered by the NCDOT in concert with the Department of Crime Control and Public Safety – Division of Emergency Management and State Highway Patrol. The reversal plan is detailed and thorough. However, an in-depth traffic operations analysis has not been performed for the plan, and the NCDOT has specific concerns about the plan operation.

The proposed two-year project will address these concerns. The first year will include a review of relevant literature; review and assessment of evacuation experiences in NC and other states; data assessment, collection and assembly; model scoping and selection of modeling tools; and development of evacuation scenarios. Given the critical need to assess the operational characteristics at the beginning of the reversal, the first year will also include focused modeling of the transition to contraflow and presentation of the preliminary findings from this modeling effort.

The second year will include modeling of the entire lane reversal plan, presentation of interim findings, incorporation of NCDOT feedback into final model runs, and preparation of the project final report. Based on the NCDOT feedback and direction, the final modeling phase will likely involve assessment of possible changes to the current lane reversal plan.

SUMMARY PAGE

Following the unprecedented multi-state coastal evacuation for Hurricane Floyd in 1999, the NCDOT developed a lane reversal plan for I-40 to facilitate the safe and efficient evacuation of residents and tourists in southeastern North Carolina. The plan, approved in 2000, was developed and will be administered by the NCDOT in concert with the Department of Crime Control and Public Safety – Division of Emergency Management and State Highway Patrol. The reversal plan is detailed and thorough. However, an in-depth traffic operations analysis has not been performed for the plan.

The NCDOT has specific operational concerns related to –

- The sufficiency of capacity at the beginning of the contraflow configuration in Wilmington
- The safety and efficiency of vehicle movements at the interchanges that will remain open during the reversal
- The lane reversal terminus and transition to normal lane usage via median crossover in the final freeway segment southeast of the I-95 interchange

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RESEARCH PLAN

Introduction and Problem Definition

The hurricane threat faced by coastal North Carolina communities is certainly not new. However, the rapid growth of permanent and seasonal populations along the coast has greatly increased the scale of risk in terms of worst case scenarios for human catastrophe. As a case in point, the Census Bureau's 2001 estimate of the resident population of New Hanover County was 163,455. This represents a 55% increase over the 1981 estimate of 105,368 and a near doubling of the 1971 estimate of 87,400. The situation is further exacerbated by the fact that peak seasonal populations along the coast have grown at even more impressive rates, and these peak populations occur during the tropical storm season. The end result is that North Carolina and her sister states must now be prepared to manage the safe, orderly and efficient evacuation of increasingly large numbers of people when coastal areas are imminently threatened by major hurricanes.

In response to this need, many states have developed plans to institute lane reversal or contraflow operations on major routes leading inland during the critical periods of peak evacuation traffic demand. Following the Hurricane Floyd evacuation of 1999, the NCDOT developed such a plan for contraflow operation on approximately 90 miles of I-40 beginning in the City of Wilmington and ending just prior to the I-95 interchange. Although well-conceived and thoroughly planned, the plan has yet to be implemented, and data on evacuation route lane reversal operations is limited given the relative newness of the concept. In particular, the NCDOT has concerns about the operations at the beginning of the lane reversal where surface streets will load Wilmington and barrier island traffic onto I-40, the operation of the interchanges under contraflow configuration, and the terminus of the reversal where contraflow operation will be ended by means of a median crossover within the final six mile segment prior to the I-95 interchange.

The proposed project will provide answers in response to these concerns through a combination of expert input, review of documentation and data on previous lane reversal experience, data collection, and simulation and analytical modeling. The proposed scope of work is summarized by task in the *Research Methodology and Itemized Tasks* section below.

Research Objectives

The overall goal of this research plan is to provide NCDOT with a thorough traffic engineering analysis and assessment of the I-40 lane reversal plan under realistic evacuation scenarios. The following research objectives will support this operational traffic analysis goal.

1. Develop a range of evacuation scenarios that include time-dependent origin-destination based estimates for the evacuation traffic demand

2. Analyze the I-40 reversal plan under the evacuation scenarios using appropriate simulation and analytical modeling tools

3. Assess the safety and operational efficiency of the I-40 plan and analyze possible modifications to the current plan

4. Provide the NCDOT with a tool that can be used for ongoing analysis and maintenance of the I-40 reversal plan

Literature Review

A targeted literature review will be conducted as task 1 of this project. However, the level of effort required to assemble an up to date summary of the literature on modeling and analysis of coastal evacuation will not be excessive because two recent reviews, Wolshon et al. (2001) and Urbina (2002), provide comprehensive treatment of the subject. The objective of the literature review conducted for this project will be to fill in gaps and include recent publications and reports.

Hurricane evacuation modeling dates back to the MASS eVACuation (MASSVAC) macroscopic evacuation model of Hobeika et al. (1985). Microscopic modeling tools that have been developed or used for hurricane evacuation analysis include the Oak Ridge Evacuation Modeling System (OREMS) (ORNL 1995), FHWA's CORSIM model (Ford et al. 2000), and Paramics (Church and Sexon 2002). However, none of the previous modeling applications have been implemented at the level of detail necessary, in terms of time dependent origin/destination estimates, to effectively analyze operations at the points of transition to and from contraflow operations and the interchange and freeway segment operations in between. Furthermore, Luo et al. (2002) recently pointed out technological enhancements that would improve evacuation traffic analysis. Therefore, the project literature will play a key role in laying the foundation for selection of the modeling tool or collection of tools that will provide the most thorough and robust analysis currently available.

Overall Work Plan

The overall work plan includes background tasks and a detailed modeling of the southeastern end (the beginning) of the I-40 reversal plan in the first year. The second year will involve continued data collection and analysis, modeling of the entire reversal plan, development and modeling of plan modifications as appropriate, and a series of presentations leading up to the final project report and presentation

Research Methodology and Itemized Tasks

<u>Task 1, Review Literature.</u> Published literature relating to coastal evacuation will be thoroughly reviewed and summarized. Examples of relevant articles are included in the final section of this pre-proposal.

<u>Task 2, Review Evacuation Experiences.</u> North Carolina and many other coastal states have gone through recent coastal evacuations for storms such as Hurricane Floyd in 1999 (NC, SC and

GA) and Hurricane Lilly that struck the Louisiana coast earlier this month. Some of these evacuations involved contraflow operation. Not all of these experiences are documented in the literature. This task will include discussions with knowledgeable experts and professionals involved in the evacuations to glean lessons learned and anecdotal data relevant to the I-40 operational analysis and modeling effort.

Task 3, Investigate Previous Analysis Efforts. There have been some evacuation plan operational analysis efforts by other states. We will conduct a comprehensive scan of evacuation/contraflow modeling done by other states and summarize the advantages, disadvantages and overall performance of the modeling and analysis tools used. This task will also include documentation of relevant evacuation modeling and analysis done on coastal evacuation routes within North Carolina.

Task 4, Data Assessment and Collection. The task of identifying data that are available for use in the operational analysis effort will commence at the beginning of the project and run concurrently with the first three tasks. Reasonableness in the modeling results will be directly related to the levels of quality and completeness of the data. Data needs fall into two primary categories – 1) travel demand and 2) operational parameters.

Travel demand estimation will require estimation of the level of compliance with evacuation orders, the origin and destination of evacuees, and the timing of evacuee departure. Origin data is available in FEMA and NC Division of Emergency Management data and evacuation models and in the FHWA ETIS model. Local planning data should also prove helpful in improving vehicle origin information. Data on destinations and departure timing in evacuation situations will be more difficult to obtain. One source is the phone survey data gathered by Dr. E. J. Baker for the Floyd evacuation. However, the destination information in the Baker survey and report is not detailed. Panel surveys and local expert assessments by team member, Dr. Stephen Meinhold, will contribute to completing estimated origin-destination (O/D) tables. Local information will be augmented by evacuation patterns documented in other states, such as the results of the post-Floyd South Carolina household survey by Dow and Cutter (2002).

Data on the operating characteristics of freeway segments and ramps under contraflow operation in mass evacuation conditions is sparse. The SCDOT developed contraflow capacity estimates based on observation of contraflow operation on I-26 during the Hurricane Floyd evacuation. We will assess the rigor of these capacity estimates and discuss with the NCDOT this accuracy assessment along with an assessment of the modeling implications. If necessary, we will confer with the NCDOT on the appropriateness of gathering additional data to strengthen the operational parameter estimates in light of schedule, budget and modeling accuracy considerations. As an example, traffic data could be collected at median crossovers in NC that are associated with freeway work zones that may be similar in pattern to the proposed I-40 crossover.

Task 5, Define Model Scope and Select Appropriate Modeling Tools. After reviewing previous modeling efforts and considering the nature of the input data and the desired model outputs, the model extents will be defined and the most appropriate analysis tool or tools will be selected in consultation with the NCDOT. Although the project team does not have firm preconceptions on

the most appropriate modeling tools, we do feel strongly that the modeling and analysis should be based on best estimates of O/D tables for the evacuation traffic. Analyses of vehicle loading at the lane reversal beginning, intervening interchange operation, and the transition to normal lane usage will be unreliable and of greatly diminished utility if based on synthetic O/D tables or turn movement balancing. In this task we will evaluate both link-based models such as CORSIM and SIM-TRAFFIC as well as path-based (O/D) models such as VISSIM, PARAMICS and OREMS. The research team is well versed in the use of the first four models, and will evaluate the utility of the OREMS model if it is deemed appropriate for the purpose of this study.

Task 6, Develop Evacuation Scenarios. Estimating the extent and timing of evacuation response is a complex behavioral analysis problem. Prediction of the time, storm strength, and location of hurricane landfall is a complex meteorological problem. Both of these primary components of the coastal evacuation equation, notwithstanding the significant advances in the related sciences, continue to be fraught with uncertainty. The Governor and the Secretaries of Transportation and Crime Control and Public Safety will be balancing these uncertainties as they contemplate the issuance of evacuation orders and the implementation of the lane reversal plan. Based upon synthesis of local and regional information and in consultation with local experts and decision makers and with the Division of Emergency Management, we will develop a series of evacuation scenarios to be evaluated using the selected analysis and modeling tools. Scenarios will range from likely to worst case and will be designed to test the sensitivity and robustness of the lane reversal plan.

Task 7, Model the Southeastern End of the Lane Reversal. Evacuees from the city of Wilmington and adjacent towns and barrier islands experienced extreme delays in reaching I-40 in the Hurricane Floyd evacuation. A reasonable operational concern is whether the planned surface street configuration at the beginning of lane reversal operations will provide adequate throughput to make efficient use of the additional outbound freeway capacity provided by the contraflow lanes. If the answer is yes, then the lane reversal plan should reduce the initial delay in reaching the freeway. However, if the surface street configuration feeding I-40 is a significant choke point, the four outbound lanes could be starved at the beginning and evacuees between I-40 and the coastline may experience very little improvement in the initial leg of their evacuation.

Other important operational factors at the beginning of contraflow operation are the restriction that heavy vehicles must use the normal outbound lanes and the use of highway patrol personnel for traffic control. Depending on the predominant directions from which heavy vehicles will be approaching I-40 and the timing of their evacuation, these movements could have a significant impact on the capacity of the feeder network. If so, additional measures to better manage heavy vehicle flows will be developed and evaluated. Likewise, if traffic control by state troopers appears to be a limiting factor, the model can also be used to evaluate alternatives that include the use of existing signal systems with special phasing plans.

Therefore, an expedited modeling task will be undertaken in the first year to analyze the traffic operation in the feeder network for the southeastern end of the lane reversal plan. As applicable, the feeder network will be subjected to the full range of evacuation scenarios. If this analysis reveals obvious deficiencies in the design of the transition to contraflow, this task can

immediately turn to the analysis of alternate surface street configurations and traffic control and management strategies.

Task 8, Model the Entire Lane Reversal Plan. The feeder network model will be rolled into the full extent model of the entire lane reversal plan. An initial round of modeling will subject the model to the evacuation scenarios. The results of these model runs will be presented to the NCDOT. In addition to assessing the performance of the lane reversal plan under each of the evacuation scenarios, this initial modeling round will give a sense of the expected capacity of the lane reversal plan and identify choke points and problem areas. We anticipate that discussion of these results with the NCDOT will lead to possible plan modifications that will in turn be incorporated into the model and analyzed. This task will add detailed assessment of the interchanges and lane reversal terminus to the results of task 7.

Task 9, Final Report and Presentations. We will prepare a final summary report with an accompanying Powerpoint presentation highlighting the project's key findings and recommendations. All supporting information including modeling details and interim findings will be organized in appendices to the final report.

Open and informal communication with NCDOT and other stakeholders throughout the course of the project will be critical to the project's success. Additionally, at critical points during the project, we will prepare and deliver formal presentations on interim findings for targeted stakeholder audiences as needed and as directed by the NCDOT.

ANTICIPATED RESULTS AND SIGNIFICANCE

The primary research product will be a summary report documenting the analysis and modeling effort and the principal findings. Byproducts of the project will include a synthesis of current practices for the development and assessment of lane reversal plans and a methodology for detailed operational analysis of such plans. Should NCDOT choose to purchase the modeling tool selected in this research, its staff will also acquire the capability of testing other evacuation scenarios and traffic operations measures beyond the duration of this study. In this case, it may be appropriate to provide training for selected NCDOT staff on the use and calibration of the model.

The significance of this effort cannot be overstated. The study will either document the efficiency and appropriateness of the existing plan or reveal changes that are needed. Even if no significant modifications in the existing plan are required, the detailed traffic analysis will provide additional insight into how the contraflow plan will function. This insight will enable the responsible individuals and agencies to be even better prepared for implementation of the I-40 lane reversal plan.

RECOMMENDATIONS FOR IMPLEMENTATION AND TECHNOLOGY TRANSFER

- What is the primary product? The primary product from this research will be a detailed traffic analysis of the I-40 lane reversal plan.

- What are the secondary products? Secondary products will include modifications to the plan is necessary and a methodology for evacuation traffic analysis.

- Who within NCDOT will use the products? The products will be used by the key players in the NCDOT, both in central office operations units (principally the head of the ITS operations unit, Kelly Hutchinson) and Division 3. The products will also be used by responsible Department of Crime and Public Safety units.

- Why should they use the products? These products will directly enhance the efficiency and safety of coastal evacuation traffic operations.

- How will they use such products? The products will enable detailed assessment of the I-40 lane reversal operations and allow for evaluation of plan modifications. By sharing the final report with other states, the NCDOT will provide important input to the coordinated efforts of the Atlantic and Gulf coast states to continually improve policies and procedures for coastal evacuation. The project findings documented in the report may also have applicability to plans for other types of mass evacuations.

- What is needed for NCDOT customers to use the products? Once the research is complete, the NCDOT will be able to directly use the information in the final reports and presentations. If NCDOT has or procures licenses for any analysis tools used in the modeling effort, then with minimal staff training, NCDOT will be able to do future in-house traffic analyses.

RESOURCES TO BE SUPPLIED BY NCDOT

Besides advice supplied by the technical advisory committee and others contacted during various tasks, the only resource to be supplied by the NCDOT during the project will be access to internal databases such as vehicle count and classification data.

EQUIPMENT AND FACILITIES

NC State, ITRE and UNC-W have the computer hardware and software licenses necessary to complete this project. The project team also has any necessary data collection equipment should such equipment be needed.

TIME REQUIREMENTS

We plan to complete the project within 2 years—by June 30, 2005. Due to the critical nature of the contraflow transition in Wilmington, the project includes a focused and accelerated modeling of this end of the lane reversal plan to be completed in the first year. This schedule allow the project team to address the NCDOT's most pressing question quickly while not short changing the overall plan modeling effort. Figure 1 shows the complete task-by-task schedule.

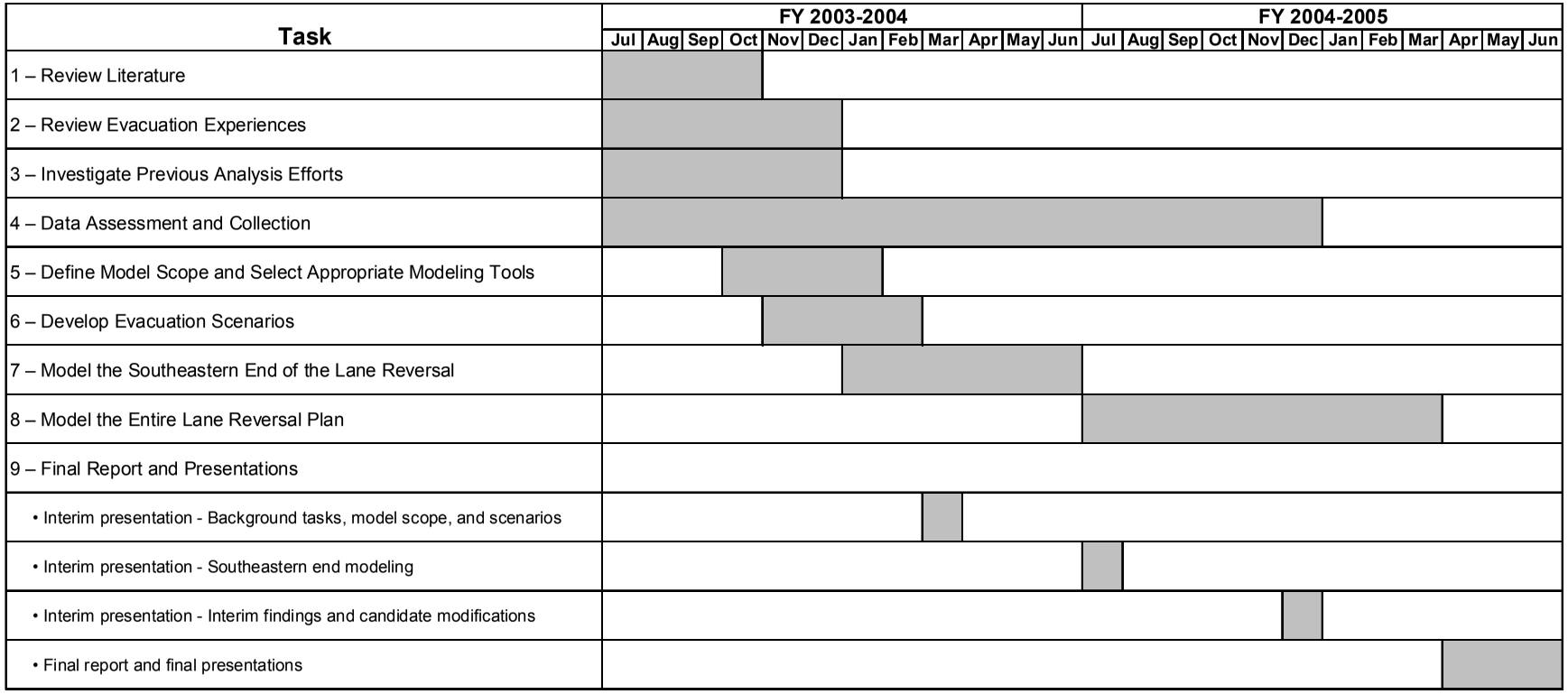

Figure 1 - I-40 Reversal Operational Traffic Analysis - Project Schedule

QUALIFICATIONS AND ACCOMPLISHMENTS OF THE RESEARCHERS

Billy M. Williams, Stephen S. Meinhold, Nagui Rouphail and Joseph E. Hummer are highly qualified to achieve the objectives of the proposed project. Dr. Williams will serve a principal investigator overseeing the entire project and leading the traffic analysis and modeling tasks. Dr. Meinhold will serve as co-principal investigator and will lead efforts related to evacuation behavior and its relationship to the timing and destination of evacuation traffic. Drs. Rouphail and Hummer will contribute their considerable expertise to the project by providing technical review and advice on simulation modeling and saturation flow under evacuation conditions, respectively.

Dr. Billy M. Williams, P.E. is an Assistant Professor of Civil Engineering at NC State. He joined the NC State faculty in August 2002 after serving three years on the civil engineering faculty at Georgia Tech. Prior to his doctoral studies at the University of Virginia, Dr. Williams was a consulting engineer and project manager for Kimley-Horn and Associates for 5 ½ years. His consulting work covered the full range of transportation planning, operations and design including projects such as –

- Master planning for the NC Global Transpark
- Concept design for roadway and streetscape improvements in the Waterside/Nauticus area of Norfolk
- Signal system feasibility studies for the Burlington/Graham and Salisbury urban areas

Dr. Williams' consulting work also included numerous traffic engineering and safety studies throughout North Carolina and in other states including Michigan, Illinois, Alabama and Arkansas.

Dr. Williams' has contributed to six archival journal articles in addition to numerous technical reports, conference proceedings and invited seminars. His research focus is in the optimization of the efficiency and safety of traffic operations with emphasis on –

- Traffic flow theory
- Traffic modeling and simulation
- Applied statistics using dynamic and archived traffic data

He served as principal investigator for a guardrail delineation project for the Georgia DOT and was instrumental in establishing intelligent transportation systems research labs at the University of Virginia and Georgia Tech. In 2002, Dr. Williams was awarded a National Science Foundation *Faculty Early Career Development* grant for his proposal titled "System-wide Traffic Condition Monitoring and State Estimation for Intelligent Transportation Systems."

Dr. Stephen S. Meinhold is Associate Professor of Political Science at the University of North Carolina at Wilmington. He has been on the UNC-W faculty since completing his doctoral studies in 1995. Dr. Meinhold received his Ph.D. in political science from the University of New Orleans. Prior to joining the UNC-W faculty, he served as Assistant Director of the Environmental Social Science Research Institute at the University of New Orleans.

Dr. Meinhold has worked closely with New Hanover County Emergency Management to examine the hurricane evacuation behavior of New Hanover County residents after Hurricane Fran in 1996 and Hurricane Floyd in 1999. He has made numerous presentations to professional audiences on this work including the National Hurricane Conference and the 2001 East Carolina Natural Hazards Conference.

Dr. Nagui Rouphail is currently Director of the Institute for Transportation Research and Education, and Professor of Civil Engineering at North Carolina State University. He received a Ph.D. from Ohio State University in 1981. Dr. Rouphail is a nationally and internationally recognized expert in the areas of highway capacity, traffic control and theory and traffic simulation modeling. He has over sixty refereed journal papers and has research expenditures as PI or Co-PI exceeding $3.5M. He is well versed in the application of traffic simulation models for urban networks, including the use of the CORSIM, VISSIM and PARAMICS models. Dr. Rouphail served as Chairman of the National ASCE Committee on traffic operations and is on several editorial boards of national and international transportation journals. He has served as PI or co-PI on at least six previous and ongoing NCDOT projects.

Dr. Joseph E. Hummer, P.E. is Associate Professor of Civil Engineering at NC State University, where he has taught and researched traffic operations and safety for 11 years. Previously, he was on the faculty at UNC Charlotte, worked for a consulting company, and served as a Graduate Research Fellow at the Federal Highway Administration. Dr. Hummer has authored or co-authored 40 papers for peer-reviewed journals, and has served as Principal Investigator for 25 research projects for a variety of federal, state, local, and private sponsors. For this project, Dr. Hummer will provide advice on saturation flow and capacity data collection, intersection and interchange design, and simulation modeling.

In the area of saturation flow and capacity data collection, he has performed numerous similar tasks on projects through the years, including several for the NCDOT in freeway work zones, three-lane cross-sections, and arterial intersections. In addition, Dr. Hummer was Associate Editor and author of eight chapters in ITE's *Manual of Transportation Engineering Studies*, the nation's premier reference on how to conduct studies of saturation flow, capacity, and similar variables. In the area of intersection and interchange design, Dr. Hummer has written over 10 papers on innovative strategies to move more vehicles through less space. In the course of this work, he has developed three new designs that have been published in peer-reviewed papers. Finally, in the area of simulation modeling Dr. Hummer is an expert in the use of the CORSIM model developed by FHWA. He has used the model on a wide variety of projects through the years, simulating everything from small urban streets to complex freeway systems, and has taught the use of the CORSIM model in NC State courses and short courses for 10 years.

OTHER COMMITMENTS OF THE RESEARCHERS

The PI and Co-PIs will have plenty of time available to complete this project as budgeted. Their current time commitments as of July 2002 are as follows:

Williams

- CAREER - System-wide Traffic Condition Monitoring and State Estimation for Intelligent Transportation Systems, NSF, June 2002-May 2007 (8%).

Meinhold

- *Pending* – Environmental Behavior of Animal Feeding Operations (AFOs): Voluntary Participation, Regulatory Compliance and Innovation Adoption – Jun 2002- Jun 2005 (8%)

Rouphail

- Incident Management Assistance Patrols—IMAP (NCDOT): 8 % in 2003.
- False Capacity for Lane Drops (NCDOT): 4% in 2003 and 4% in 2004.
- NC LOS Program (NCDOT): 6% in 2003 and 6% in 2004.
- In-Vehicle Energy and Emissions Information Systems (NSF), 8% in 2004.

Hummer

- Operations of Shared Use Paths, FHWA, Oct 2000-Sep 2003 (10%).
- Communicating Changes in Horizontal Alignment, NCHRP, Jan 2001-Aug 2003 (7%).
- Railroad Crossing Wayside Horn Evaluation, NCDOT, Jul 2002-Jun 2004 (6%).
- False Capacity for Lane Drops, NCDOT, Jul 2002-Jun 2004 (15%).
- Effects of Increased U-Turns at Intersections on Divided Facilities and Median Divided Versus Five-Lane Undivided Benefits, NCDOT, July 2002-June 2004 (12.5%)

CITED PUBLICATIONS BY PROPOSING RESEARCHERS

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2. Hall, F., D. May, N. Rouphail, L. Blomberg and B. Eads (2000) "Validation Results for Four Models of Over Saturated Freeway Facilities", *Journal of the Transportation Research Board* 1710, pp. 161-170. Best Paper Award for TRB A3A10 Committee.
3. Hummer, J.E. (2002). "Transportation Engineering Analysis of the Proposed Widening of US-1 Between Florida City and Key Largo," Florida Keys Citizens Coalition, Islamorada, FL, July 2002.
4. Meinhold, S.S. and Jones, L.P. (1998). "New Hanover County/Wilmington Project Impact Public Attitudes and Preparedness Study: Executive Summary." New Hanover County Department of Emergency Management: New Hanover County, North Carolina.
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Oceanic and Atmospheric Services Center. NOAA/CSC/99044-CD. CD-ROM. Charleston, SC: NOAA Coastal Services Center.
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7. Smith, B., Williams, B., and Oswald, R. (2002). "Comparison of Parametric and Nonparametric Models for Traffic Flow Forecasting." *Transportation Research, Part C*, Vol. 10, No. 4, pp. 303-321.

CITED PUBLICATIONS BY OTHERS

1. Baker, E.J. (2000). "Southeast U.S. Hurricane Evacuation Traffic Study Behavioral Analysis," Hazards Management Group, Tallahassee, FL.
2. Dow, K. and Cutter, S. (2002). "Emerging Hurricane Evacuation Issues: Hurricane Floyd and South Carolina." *Natural Hazard Review*, Vol. 3, No. 1, pp. 12-18.
3. Franzese, O. and Han, L. (2001) "Traffic Modeling Framework for Hurricane Evacuation." Technical Paper No. 01-2591, Transportation Research Board 80th Annual Meeting, Washington, D.C., January 2001.
4. Hobeika, A.G., Radwan, A.E., and Jamei, B. (1985). "Transportation Actions to Reduce Evacuation Times Under Hurricane/Flood Conditions: A Case Study of Virginia Beach City." Transportation Research Board Annual Meeting.
5. Miller Consulting, Inc. (2001). "Florida Keys Hurricane Evacuation Study: Final Report," Florida DOT, Division Six, Miami, June 2001.
6. Nelson, C., et al. (1989). "Models of Hurricane Evacuation Behavior," Department of Psychology, University of South Florida, Tampa, 1989.
7. ORNL (1995). "Oak Ridge Evacuation Modeling System (OREMS), User's Guide." Oak Ridge National Laboratory.
8. Post, Buckley, Schuh and Jernigan (2000). "Reverse Lane Standards and ITS Strategies - Southeast United States Hurricane Study Technical Memorandum Number 1: Final Report," June 2000.
9. Ubina, E. (2002). "A State-of-the-practice Review of Hurricane Evacuation Plans and Policies." Master's Thesis, Louisiana State University.
10. Wolshon, B. (2001). "'One-Way-Out': Contraflow Freeway Operations for Hurricane Evacuation." *Natural Hazards Review*, Vol. 2, No. 3, pp. 105-112.
11. Wolshon, B., Urbina, E. and Levitan, M. (2001). *National Review of Hurricane Plans and Policies*." Louisiana State University Hurricane Center.